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A LABORATORY SYSTEM FOR AIR INTERCEPT CONTROLLER TRIANING.(U)

JAN 79 R M ANDERS, M W GRADY, L H NOWELL N61339-78-C-0053

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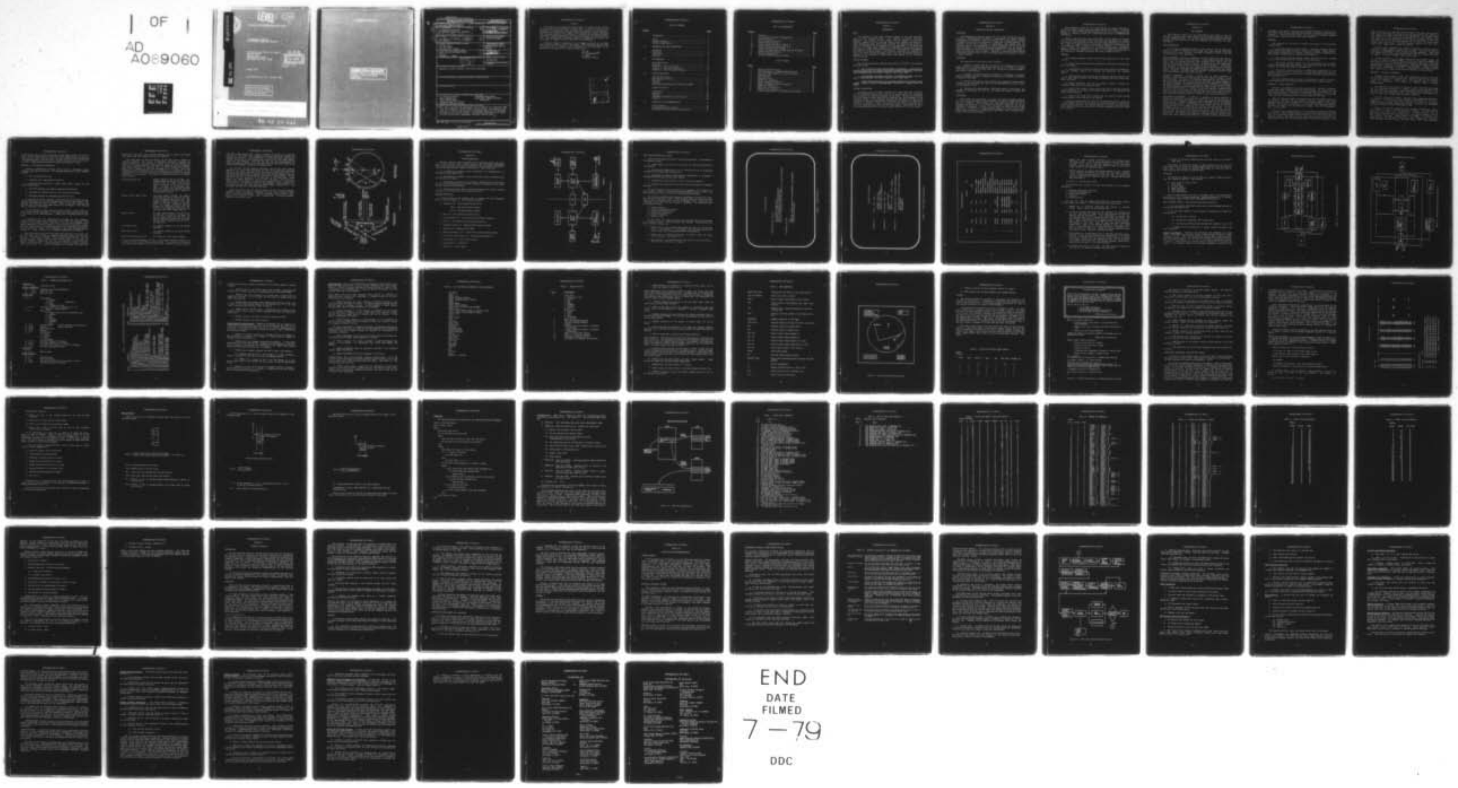

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TECHNICAL REPORT NAVTRAEQUIPCEN 78-C-0053-1

A LABORATORY SYSTEM FOR AIR INTERCEPT CONTROLLER TRAINING

R.M. Anders, M.W. Grady, L.H. Nowell,
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Post Office Box 80158
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January 1979

Final Report March 1978 - November 1978

DoD Distribution Statement

Approved for public release;
distribution unlimited.

NAVAL TRAINING EQUIPMENT CENTER
ORLANDO FLORIDA 32813

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

18 17

1. REPORT NUMBER: NAVTRAEQUIPCEN 78-C-0053-1

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

6

4. TITLE (and Subtitle): A LABORATORY SYSTEM FOR AIR INTERCEPT CONTROLLER TRAINING

9

5. TYPE OF REPORT & PERIOD COVERED: Final Report, March 1978 - November 1978

6. PERFORMING ORG. REPORT NUMBER:

10

7. AUTHOR(s): R.M. Anders, M.W. Grady, L.H. Nowell, M.A. Overton

15

8. CONTRACT OR GRANT NUMBER(s): N61339-78-C-0053

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Logicon, Inc.
P.O. Box 80158
San Diego, CA 92138

LPN

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NAVTRAEQUIPCEN Task No. 7796-2P1

11. CONTROLLING OFFICE NAME AND ADDRESS:
Naval Training Equipment Center
Code N71
Orlando, FL 32813

11

12. REPORT DATE: January 1979

13. NUMBER OF PAGES: 71

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

12 75p.

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report):
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Air Intercept Control
Speech Recognition
Speech Understanding
Automated Adaptive Training
Controller Training Systems
Performance Measurement
Intelligent Computer Assisted Instruction

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This report describes the development and utilization of a laboratory model of an air intercept controller (AIC) training system. The purpose of the model was to identify and validate instructional features of an automated and adaptive AIC training system. A preliminary specification of simulation and instructional requirements resulted from the study.

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Foreword

This report is the second and final report of a series in the analysis of the job of the Air Intercept Controller (AIC). A fully functional, working model was developed in order to enhance the evaluation of the concept of automated AIC training using computer speech recognition, speech synthesis, and a computer model of the instructor. Hands-on use increased technical information interchange between instructional personnel and systems personnel. The working model provided a medium of communication between the disciplines of computer science, education, and psychology.

Heartfelt thanks are extended to the command and staff of the Fleet Combat Training Center, Pacific, San Diego. LCDR Cleveland, OSCS Billups, OSC Lindsay and Mr. Spencer proved invaluable in the refinement of the functional specification for an AIC training system.

R. BREAUX
Scientific Officer

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SECTION I

INTRODUCTION

SCOPE

This document is the final technical report for the work performed under contract N61339-78-C-0053: Air Intercept Controller Front-End Analysis. The purpose of this project was to identify instructional features required for Air Intercept Control (AIC) training and develop a fully functioning model which would validate the features and provide a basis of discussion on new approaches to AIC training. By avoiding the pitfalls of a "paper-model" analysis, the Government's intent was to ensure the validity of the instructional features of the subsequent experimental prototype AIC training system. This document, therefore, is intended for use by the Naval Training Equipment Center and other interested parties in support of the definition, specification, and design of the prototype training system.

RELATED DOCUMENTS

The following documents describe work which is related to the efforts discussed herein:

a. Use of Computer Speech Understanding in Training: A Demonstration Training System for the Ground Controlled Approach Controller; Technical Report NAVTRAEQUIPCEN 74-C-0048-1; Logicon, Inc.; July, 1976.

b. Air Intercept Controller Training: A Preliminary Review; Technical Report NAVTRAEQUIPCEN 77-M-1058-1; Logicon, Inc.; June, 1977.

c. Speech Understanding in Air Intercept Controller Training System Design; Technical Report NAVTRAEQUIPCEN 78-C-0044-1; Logicon, Inc.; in press.

DOCUMENT ORGANIZATION

Following these introductory remarks, the report discusses in Section II the background against which this study was conducted, and formulates more precisely the problems addressed in the study. Section III describes the three scenarios which served as the framework for the development of the laboratory model. A more detailed discussion of that model, including brief hardware and software descriptions, is presented in Section IV. The report continues in Section V with a discussion of the results uncovered as a result of developing and using the laboratory model. Conclusions are drawn and recommendations made in the final section (Section VI) of this report.

SECTION II

BACKGROUND AND TASK DESCRIPTION

BACKGROUND

The Demonstration Training System for the Ground Controlled Approach Controller, NAVTRAEQUIPCEN 74-C-0048-1, demonstrated that advanced speech technologies and automated training techniques can be successfully applied to enhance the quality of instruction in controller training systems. Air Intercept Control (AIC) training is considerably more complex than GCA training, both in the requirements of speech recognition and in the learning requirements. The GCA-CTS experience demonstrated that the design of training systems can often benefit by development of a laboratory model to assess the technical and cost risks. Moreover, a laboratory system enables a front-end analysis using a fully functioning model not possible in a purely paper analysis.

OBJECTIVES

The objectives of this project were fourfold:

a. Develop a system which would facilitate the demonstration of automated controller training capabilities and act as a catalyst to promote discussion of required functions among AIC instructors, system designers, and research psychologists.

b. Provide a pseudo-training environment for evaluation of instructional strategies and skill assessment techniques by automated performance measurement technology.

c. Provide a test-bed for new algorithms for automatic computer speech recognition, so that high risk areas can be identified early in the prototype development effort.

d. Determine the requirements, investigate design alternatives, and estimate the implementation costs for the simulation needed to support AIC training.

CONSTRAINTS

This project was constrained by a number of factors including hardware selection, speech technology to be addressed, and extent syllabus automation was to be examined. The hardware suite upon which the model was to be developed and exercised is the system concurrently supporting the GCA-CTS experimental prototype. Briefly, this includes two Data General Eclipse computers, a 10 MByte disc, a Megatek MG552 display, two CRTs, a Tally high-speed character printer, a Votrax speech synthesizer, and a Threshold Technology voice input preprocessor.

The development effort was also constrained by the speech technology to be studied, namely Limited Continuous Speech Recognition (LCSR). The development of a speech understanding subsystem for use in AIC training was the subject of a parallel effort and is described more fully in NAVTRAEQUIPCEN 78-C-0044-1.

Finally, the laboratory model specifically did not address the automation of the training syllabus, since this issue was considered to be similar in concept to the automated syllabus functions being implemented in the GCA-CTS. Specific elements within a functional syllabus were implemented, but no attempt was made to weave these elements together into a structural whole. However, the development of an effective performance measurement subsystem, which was studied in this effort, is a necessary prerequisite to the functions of automated evaluation and, then, syllabus control.

APPROACH

The technical approach toward satisfying the objectives of this study was to:

a. Define three scenarios which represented a sufficiently generalized set of AIC tasks.

b. Conceptualize a laboratory model which would provide the demonstration and research vehicle for studying the simulation and training issues.

c. Based upon the AIC scenarios and the model's general structure, define in more specific detail the scenario components and the system functions they imply.

d. Design, implement, and test the software needed to support the identified functions of the laboratory model.

e. Expose Fleet Combat Training Center and Naval Training Equipment Center personnel to the model, and gather feedback on its technical and instructional features.

f. Prepare this final report summarizing the lessons learned through the development and utilization of the system.

It should be emphasized here that the AIC laboratory model is viewed as a very powerful tool for the continued test and refinement of various AIC training system features. The initial exposure of the AIC prototype developers reported herein is only the first of many experiences with the system as it evolves.

SECTION III

THE SCENARIOS

The principal vehicle for the specification and design of the AIC laboratory model has been three scenarios which encompass important controller job responsibilities. This section describes these scenarios and their related learning objectives, and also presents the rationale for their selection.

BRIEF DESCRIPTION

The following paragraphs provide a brief overview of the three scenarios in order to familiarize the reader with their general functional characteristics, and to provide a preliminary framework in which to describe the rationale for their selection.

BASIC INTERCEPTS. Scenario 1 addresses the basic tasks which the AIC must perform in conducting a simple intercept. As the exercise unfolds, the AIC must locate his assigned aircraft and establish radio contact with the pilot. When a bogey (hostile aircraft) is detected, the AIC communicates with the pilot to vector him to a nearest collision intercept. As the exercise proceeds, the controller must regularly and accurately provide information to the pilot concerning the bogey's bearing, range, track, and ground speed. Scenario 1 concludes when the friendly, controlled aircraft comes into radar contact with the hostile aircraft.

REALISTIC INTERCEPTS. Scenario 2 builds upon the basic structure of Scenario 1, adding several complications that more nearly represent actual air intercepts. In addition to providing bogey position and velocity updates, the controller must now also detect and report any sudden changes in the bogey's heading, and recommend new vectors to accommodate the maneuvering hostile aircraft. Moreover, the AIC must detect the presence and report the range, bearing, track and groundspeed of other aircraft in the vicinity of the controlled aircraft. Finally, the AIC must respond to communications from the pilot at the point of radar contact, at the time when the pilot takes over the intercept himself, and when the pilot loses contact with the bogey and needs additional position, velocity, and vectoring information.

THE TRAINING ENVIRONMENT. In addition to learning to control aircraft in combat-like intercept conditions, the controller is often called upon to assist in pilot training by setting up mock intercepts in well-established training areas. Scenario 3 commences with two aircraft flying in formation toward the training area. The AIC makes radar contact with the two aircraft and establishes a lost communications procedure with the pilots. The AIC recommends vectors to the aircraft for area control and maintains the aircraft in the area by providing heading advisories. The AIC then detaches one aircraft (the bogey) and turns the other aircraft (interceptor) for separation. The controller determines a planning bearing, target aspect angle, and track crossing angle based upon the point at which he desires the intercept to take place. After getting the proper separation, the AIC turns the aircraft for the mock intercept and Scenario 3 continues as described in Scenario 2. When the aircraft merge, the AIC provides breakaway headings and Scenario 3 concludes as the two aircraft separate.

RATIONALE

The selection of the model's scenarios was guided by the following considerations.

a. The chosen scenarios should include a reasonably complete exercise of the speech technologies needed to support AIC training. These technologies included isolated word, or phrase, recognition; limited vocabulary connected speech recognition; and computer voice synthesis.

b. The chosen scenarios should include the most critical training areas, and hence stimulate the interest of AIC instructors.

c. The chosen scenarios should not be too demanding upon the simulation requirements that they impose. The resulting system must be implementable on the provided hardware configuration.

d. The chosen scenarios should be sufficiently generalized to represent a cross section of typical AIC training environments in order to provide validity to technical and cost estimates based upon experience with the laboratory model.

As will be demonstrated when they are described in detail in the following subsections, the chosen scenarios satisfy each of these criteria.

SCENARIO 1 - BASIC INTERCEPTS

Scenario 1 encompasses four learning objectives: check-in procedures, vectors for bogey, bogey bearing and range reports, and bogey track and ground speed reports. These objectives represent basic tasks which the AIC will routinely perform. Scenario 1 provides an environment in which these tasks and their corresponding skills can be taught and practiced.

When the intercept begins, the range scale is at 64 miles, ownship is off center to the east, and the Combat Air Patrol's (CAP's) video (radar presentation) and friendly symbol are in orbit approximately 15 miles from ownship. The symbol is being kept on its video via a simulated tracker. The CAP's call sign is the tactical call of Snake. The CAP is squawking a Mode 2 code of 5201.

The AIC's first responsibility is to go through the check-in procedures with the CAP. This includes locating the aircraft by challenging the video until the established Identification Friend or Foe (IFF) code (5201) is returned. Next, a CAP symbol is built; this informs the Naval Tactical Data System (NTDS) that this is the aircraft which this AIC will control. To do this, the trainee will hook the friendly symbol; will enter the aircraft's Mode 2 code, the data-link address, and the link status; will observe an "F4" symbol near ownship; and will depress ORDER-SEND. The friendly symbol then changes to a CAP symbol and is removed from command tracking. From this point on, the AIC is responsible for keeping the symbol on the video. The final step in the check-in procedures is to conduct the radio check: "Snake, radio check, over." The pilot responds, "Snake is in a port (starboard) orbit, angels twenty, ready for control."

Shortly after completing the check-in procedures, a hostile aircraft (video and tracked symbol) appears from the west. The AIC uses NTDS to determine a recommended nearest collision intercept geometry. Based upon the computed vector (XXX), the AIC transmits to the CAP, "Snake, vector XXX for bogey." The pilot responds, "Roger, vector XXX."

In this, Scenario 1, the bogey continues on his original course, and the CAP is turned to command heading. The CAP and bogey are engaged, and the AIC must utilize the appropriate NTDS functions to determine the bearing and range from the CAP to the bogey, and to determine the bogey's track and ground speed. (Altitude is not addressed in this model.) These advisories are, in turn, transmitted to the CAP: "Bogey XXX,YY" and "Bogey tracking XXX, speed point X." When the CAP receives contact, the scenario ends.

SCENARIO 2 - REALISTIC INTERCEPTS

Scenario 2 builds upon the basic jobs presented in Scenario 1 and adds the following three learning objectives: report strangers in the vicinity of the CAP, respond to a course jink by the bogey (a jink is a drastic change in direction), and respond to various pilot initiated communications.

The scenario is very similar to Scenario 1 until the tracks are engaged. At this point, strangers — or unknown aircraft — enter the area. The AIC must report bearing, range, track and ground speed information to the CAP until the pilot indicates he has visual contact with the unknown aircraft, or until the stranger opens relative to the CAP.

Moreover, whereas in Scenario 1 the bogey never changes his direction, in Scenario 2 the hostile aircraft changes its heading while the CAP is engaged to it. The AIC must detect the jink, and report to the pilot: "Bogey jinking left/right...Snake, vector XXX." As before, the recommended heading to counter the jink is provided by NTDS.

Finally, the AIC must respond to pilot initiated transmissions. Recall that Scenario 1 ended as the CAP obtained a contact. At this point in Scenario 2, the pilot gives a contact call: "Contact, XXX,YY." The AIC must confirm that the pilot is reporting on the correct aircraft, and he must respond accordingly: "Roger, that is your bogey" or "Negative, your bogey XXX,YY." The controller continues to give "bogey dope" (position, track and speed information) until the pilot calls, "Judy," which indicates he has contact with the hostile aircraft and has taken control of the intercept. The AIC ceases giving "bogey dope" while staying alert for jinks or "lost contact" calls from the pilot, at which points the AIC would start relaying advisories to the CAP again. Finally, the pilot will call, "Fox 1" or "Fox 2," indicating he fired his missiles, and Scenario 2 ends.

SCENARIO 3 - THE TRAINING ENVIRONMENT

Scenario 3 addresses an ancillary job of the AIC: assisting in pilot training using mock intercepts. The learning objectives of this scenario include:

a. Pick up assigned aircraft.

b. Determine lost communications protocol.

c. Determine planning bearing, target aspect angle, angles off, and track crossing angle.

d. Plot CAP's heading, and bogey's heading and reciprocal.

e. Establish an intercept area and turn aircraft accordingly.

f. Determine headings for breakaways and area control.

At exercise initiation, ownship is off-center and two friendly aircraft (symbols and video) are in orbit approximately 20 miles from ownship. The tactical call-signs are Snake and Viper. Snake is the leader and will be the CAP; Viper is flying with Snake and will be the bogey. The training area is outlined on the screen.

The AIC conducts a radio check with both aircraft, locates the aircraft, and builds the CAP symbols. The controller then vectors the aircraft to the center of the operating area: "Snake, port (starboard) XXX for the area."

To establish the lost communication procedure the AIC transmits, "Snake, say lost comunications intentions, over." The pilot responds, "This is Snake, point whiskey, twenty, port orbit." The AIC will determine if any firing exercises or other aircraft will intervene the aircraft's transit from the control area to the rendezvous point. If no problems are foreseen, the AIC transmits, "Roger, out"; otherwise the AIC would recommend another rendezvous: "Tango 1, Tango 2 hot, recommend rendezvous Point Sierra."

When the aircraft are about five miles from the center of the area, the AIC will detach the aircraft by assigning diverging courses for the bogey and CAP. The AIC will transmit, "Viper, detach starboard XXX," and the bogey pilot will respond, "Viper, roger, starboard XXX." To the CAP, the AIC will transmit, "Snake, port XXX," with the response from the CAP pilot, "Snake, roger, port XXX." The directions of turns and assigned headings place the aircraft on reciprocal headings for opening the range and positioning them within the assigned operating area at points from which their next turns will commence the initial intercept.

While the bogey and CAP are opening, the AIC will solve a problem in intercept geometry. The "given" or "measured" information includes the general direction for the intercept (to which side of the line between the aircraft), the range separation from which the intercept will be initiated, the (equal) speeds of the aircraft, and the angular relationship between bogey and CAP heading at which the intercept is to be made. With this information, the AIC computes the next headings to be transmitted to the bogey and CAP; the turns will convert the two opening aircraft into closing opponents for the intercept. The solution introduces terms which are defined as follows:

Planning Bearing (Ø):	Magnetic bearing from CAP to bogey, projected between the points from which both aircraft will be turned (when desired range is reached) to initiate the intercept. If there is any bearing drift while the aircraft are opening, planning bearing is taken to the next 5 degrees in the direction of drift.
Target Aspect Angle (TAA):	The angle measure between the bogey's track and the line of sight to the CAP, or how the bogey looks at the CAP. The angular difference measured from bogey heading to the line of sight to the CAP. Also, the angular difference measured between the extended bearing line from the CAP to the bogey (Ø), measured to the reciprocal (R) of the bogey track (B).
Angle Off (AO):	The angle measure between the CAP's track and the line of sight to the bogey, or how the bogey looks from the CAP. The angular difference between the CAP heading (F) and the bearing from the CAP to the bogey (Ø).
CAP Heading (F):	The magnetic heading of the CAP during intercept.
Bogey Heading (B):	The magnetic heading of the bogey during intercept.
Bogey Heading Reciprocal (R):	The reciprocal of the bogey heading.

In this training environment, the AIC is calculating intercept courses for a "collision," with two aircraft at equal speed. This produces an intercept with equal angle measures for TAA and AO, with a steady (constant) bearing from CAP to bogey equal to Ø. Figure 1 presents an example of a geographical plot of the two aircraft approaching the area, turning for opening, and turning for intercept. Also presented is a simulated scope presentation showing projections of the bearings and tracks as the AIC would compute values for the intercept. Note that the plot and scope presentation are based on magnetic bearings and courses which the AIC uses after applying the correction for magnetic variation 15 degrees East.

To calculate for the depicted intercept, the AIC will mark planning bearing on the scope (345), add angle off (30) in the direction the intercept is to take place, and mark "F" on the scope for fighter head (315). He will apply the same number of degrees as AO (TAA) in the opposite direction from Ø, and mark "R" on the scope for reciprocal of bogey heading. The AIC then will take the reciprocal of "R" and plot "B" for bogey head. After getting the proper separation, the AIC turns the bogey. AIC transmits, "Viper, port 195 as bogey"; the bogey pilot responds, "Viper, roger, port 195 as bogey." The AIC then turns the interceptor, "Snake, starboard 315 for bogey," and the CAP pilot responds, "Snake, roger, starboard 315." The intercept continues as in the other scenarios.

When the plots of the two aircraft merge, the AIC will give breakaway headings, "Viper, port XXX for breakaway," and the pilot responds, "Viper, roger, port XXX for breakaway." The AIC transmits, "Snake, continue XXX," and the pilot transmits, "Snake, roger, continue XXX." As the two aircraft separate, the scenario ends.

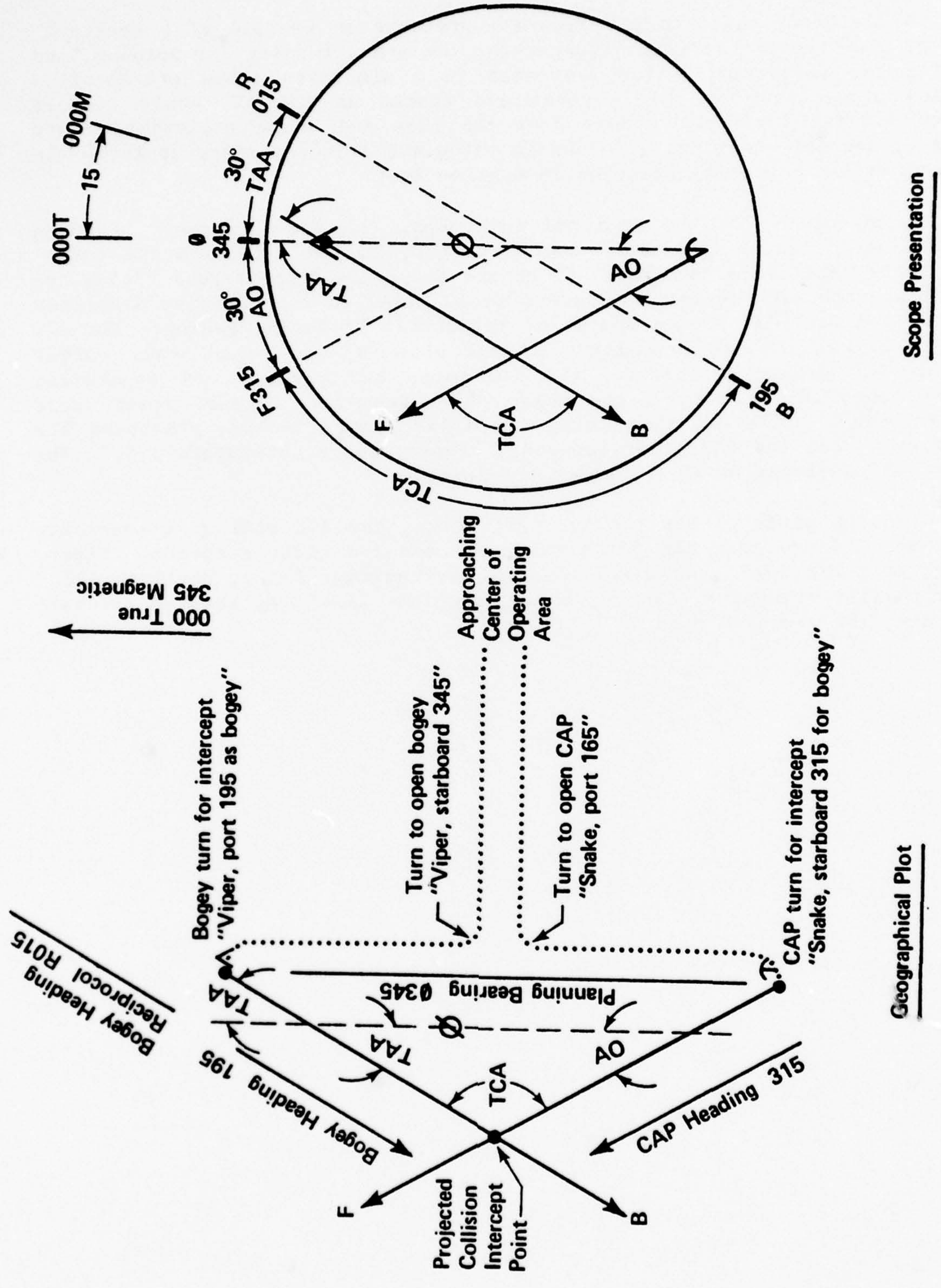


Figure 1. Scenario 3

SECTION IV

SYSTEM DESCRIPTION

The AIC laboratory model (AIC-LAB) can be organized around four areas. This division proved to be a useful artifice for the program development effort, and will also facilitate discussion of the functional characteristics and hardware/software design of the system. These areas are:

a. An Executive program, which facilitates the demonstration of implemented model capabilities

b. AIC Simulation programs, which provide the overall environment for the following two areas

c. Performance Measurement and Evaluation (PM&E) programs, which monitor the AIC's performance and provide feedback on specific errors and/or overall strengths and weaknesses

d. Teaching programs, which lead the AIC through the various learning objectives and instruct him on the requisite skills

HARDWARE DESCRIPTION

A block diagram of the hardware used to support this AIC laboratory model is shown in Figure 2. This hardware included:

a. Computers (2): Data General Eclipse S/130

CPU-1: 64K Semi-conductor memory

CPU-2: 96K Semi-conductor memory

b. Disk (1): Data General 6045 Disk Drive

c. System Console (2): Data General 6053 Display Terminals

d. IPB (1): Data General 4240 Inter-Processor Bus

e. Graphics Display (1): Megatek MG552 Graphics Display

f. Joystick (1): Megatek Joy-3 75882

g. Speech Synthesizer (1): Votrax VS-6.4 Audio Response System

h. Voice Input Preprocessor (1): Threshold Technology 500

i. Line Printer (1): Tally T1602 Printer

j. Microphone (1): Shure SM10

k. Speaker (1): Radio Shack

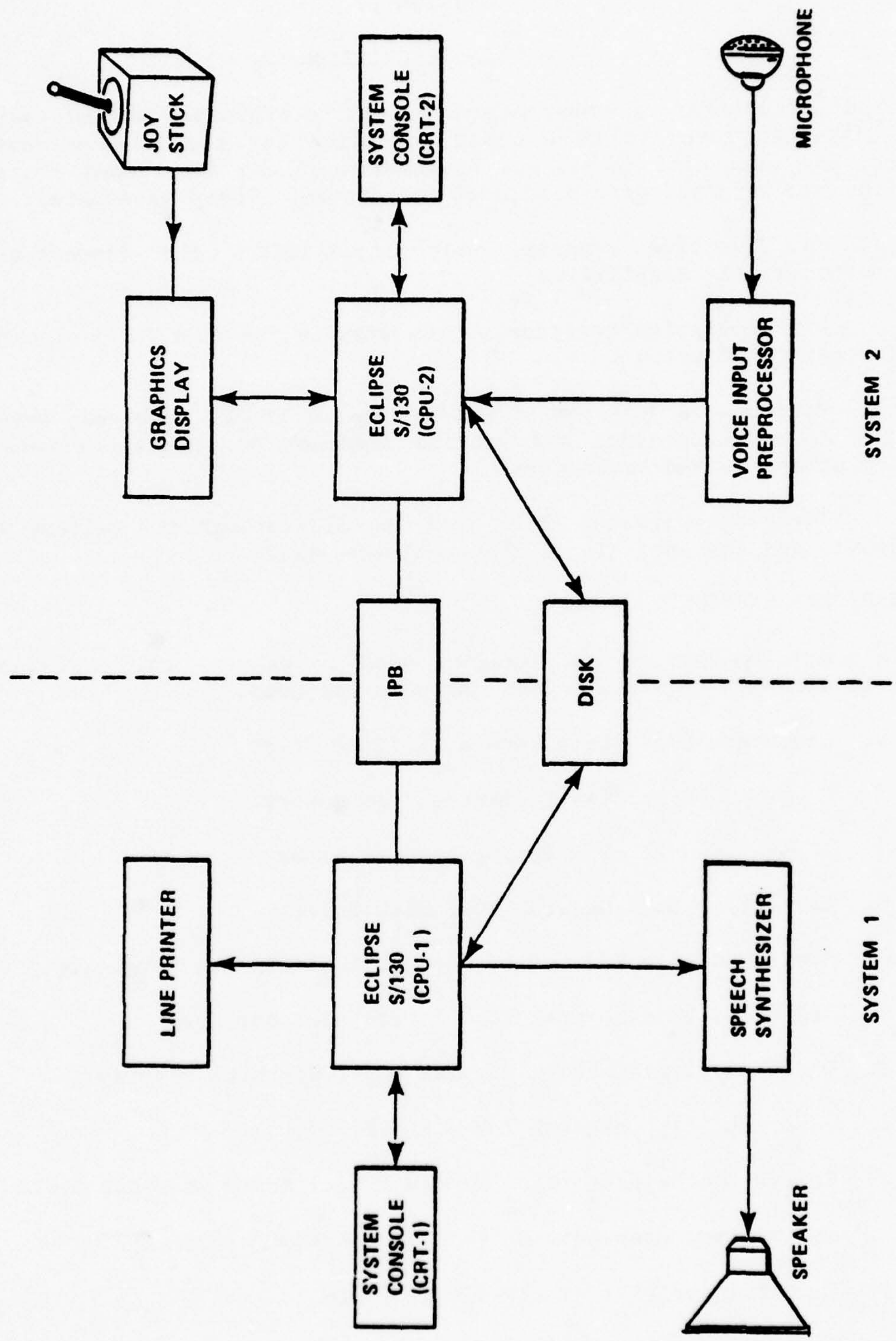


Figure 2. AIC Laboratory Hardware Configuration

MENU SELECTION/EXECUTIVE (MS/E)

MS/E is the program activated by the operating system. The purposes of the program include:

a. Communicating with the user to activate the specific AIC-LAB function desired

b. Facilitating demonstration of the AIC-LAB system by presenting overviews of the system and the scenarios

c. Suggesting automated record-handling capabilities by producing a system/user utilization log upon user request

d. Establishing synchronization of the two Eclipse computers

e. Swapping the proper save files into core for execution of requested functions

The MS/E program actually consists of two programs. The primary program resides in CPU-1; a smaller secondary program resides in CPU-2, the main functions of which are the last two items mentioned above.

The following describes the functions and designs of the MS/E in CPU-1. The user enters his name at CRT-1. MS/E validates that the user files exist (voice data, performance data, and the utilization log). Except for the voice data files, new files are created if necessary. The Operations Menu is presented on CRT-1:

1 — System Overview
2 — Scenario Descriptions (brief)
3 — System Utilization Report
4 — Voice Data Validation
5 — Scenario Selection
6 — Return to CLI

The user types the number associated with the desired option (followed by a carriage return). Invalid entries are ignored. Valid entries and their resultant actions are:

1 — Simple text is sent to CRT-1 describing the purpose of the AIC-LAB system. (See Figure 3.) MS/E pauses until the user strikes any key, at which time the Operations Menu is represented.

2 — Simple text is presented describing in general terms the three basic scenarios. (See Figure 4.)

3 — Read the user's system utilization file from the disc and format a report such as that shown in Figure 5.

SYSTEM OVERVIEW

DEMONSTRATION SYSTEM :

> ENVIRONMENT SIMULATION
> AUTOMATED STUDENT RECORD HANDLING
> SPEECH RECOGNITION & GENERATION
> LOW-COST TRAINING BASED ON COMMERCIAL-GRADE EQUIPMENT

RESEARCH SYSTEM :

> LCSR
> COMPUTER-BASED OBJECTIVE PERFORMANCE MEASUREMENT
> TEACHING APPROACHES

Figure 3. System Overview

```
                SCENARIO OVERVIEWS

SCENARIO 1 :   BASIC SKILL TASK

               >  AIRCRAFT PICK UP
               >  MAKING A CAP SYMBOL
               >  TRANSIT BOGEY INFORMATION

SCENARIO 2 :   ADDITIONAL SKILL TASK

               >  STRANGER REPORTS
               >  JINKS
               >  CONTACT / JUDY / LOST CONTACT

SCENARIO 3 :   CONTROLLING IN A TRAINING ENVIRONMENT

               >  INTERCEPT SET-UP FOR PILOT TRAINING
               >  AREA CONTROL
               >  BREAKAWAYS
```

Figure 4. Brief Scenario Description

SYSTEM UTILIZATION LOG

NOWELL 12/18/78 12:45

RUN NO.	DATE	ON	OFF	TASK
1	12/18/78	12: 9	12:13	SCENARIO 1 TEACHING
				CHECK IN PROCEDURE
2	12/18/78	12:13	12:15	SCENARIO 1 TEACHING
				BEARING-RANGE REPORTS
3	12/18/78	12:15	12:21	SCENARIO 1 FREEZE AND FEEDBACK
				VECTOR FOR BOGEY
				BEARING-RANGE REPORTS
				TRACK AND GROUND SPEED REPORTS
4	12/18/78	12:21	12:25	SCENARIO 1 PRACTICE
5	12/18/78	12:26	OPERATOR ABORTED	SCENARIO 1 TEACHING
				VECTOR FOR BOGEY
6	12/18/78	12:27	SYSTEM ABORTED	SCENARIO 2 PRACTICE
7	12/18/78	12:28	SYSTEM ABORTED	SCENARIO 2 PRACTICE
8	12/18/78	12:29	OPERATOR ABORTED	SCENARIO 2 PRACTICE
9	12/18/78	12:32	OPERATOR ABORTED	SCENARIO 2 PRACTICE
10	12/18/78	12:36	12:39	SCENARIO 2 TEACHING
				BOGEY JINKING
11	12/18/78	12:39	12:44	SCENARIO 2 TEACHING

Figure 5. System Utilization Log

4 — Update the user's system utilization file to indicate voice validation usage. Swap the Voice Validation program into CPU-2, and wait for a code to indicate termination of the validation process. Update the log file with sign-off time and clear abort flag. Return to the Operations Menu.

5 — Request the user to specify the desired scenario (1,2,3). Validate that a Scenario Definition File exists for the chosen scenario. Create a temporary communications file and write the user's name and the chosen scenario number on that file. Display the Function Menu (see below).

6 — Return to the Operating System.

The Function Menu presents the user with options to the scenarios themselves:

1 — Scenario Description (detailed)
2 — Teaching and Remediation
3 — Freeze and Feedback
4 — Practice
5 — Operations Menu

The user will type the number associated with the desired option. Invalid entries are ignored. Valid entries and their actions are:

1 — Simple text is presented describing the scenario in moderate detail. Pause. Return to the Function Menu.

2 — A list of learning objectives for this scenario are presented and the user indicates (by number entry) the objective for which he desires teaching presentation. This information is written into the temporary disk file to communicate with other save files. The user's system utilization file is updated to indicate his request. Send a code to CPU-2 to notify the MS/E in CPU-2 to load the teaching program on that side. Wait for code from CPU-2 indicating proper load. Swap in the teaching program on this side. When control is returned, wait for a code from CPU-2 to indicate MS/E is back in control on that side. Update the system utilization file with sign-off time. Return to the Function Menu.

3 — MS/E presents an all-inclusive list of learning objectives (e.g., Scenario 2 would include calling range and bearing). It requests the user to indicate those for which he wants to freeze on errors and be given feedback and then proceeds as above (save in temporary file, update utilization file, load/release programs, update utilization file, and return to the Function Menu.)

4 — No options are given to the user. The MS/E proceeds immediately with the (by now) familiar sequence detailed above.

5 — Delete the temporary communications file and return to the Operations Menu.

The portion of MS/E which resides in CPU-2 simply waits for the load codes from CPU-1, and loads the proper program (which will send the confirmation code). When control is returned, MS/E sends an "all done" code to CPU-1 and goes back waiting for another input.

SIMULATION

The simulation programs of the AIC model are common to PM&E and Teaching. (See Figures 6a and 6b.) They include:

a. Basic Scenario Control (BSC)
b. Pilot Model
c. Aircraft Model
d. Radar Simulation
e. NTDS Simulation
f. Speech Recognition

Each of these except the last is discussed from a functional/design perspective in the following paragraphs. Speech Recognition is the subject of a companion report cited earlier, NAVTRAEQUIPCEN 78-C-0044-1.

BASIC SCENARIO CONTROL. BSC performs three major functions:

a. Set up scenario conditions using time- and event-tagged entries in the Scenario Definition File

b. As the MAIN routine in each computer, orchestrate the other AIC subsystems by:

(1) Calling major routines

(2) Activating, suspending, and killing tasks

(3) Coordinating communications between the computers via the IPB

c. Interface with the AIC-LAB user to freeze, continue (proceed), and abort exercises.

Scenario Generation. Scenarios are controlled via formatted card image input. The cards may indicate either event-initiated actions or time-initiated actions. These actions generate tracks, drop tracks and modify the motion of the tracks. The format of the entries in the scenario definition file (SDF.YX where X=1, 2, or 3 and Y = a version identifier) is shown in Table 1. Events which can initiate scenario functions are presented in Table 2. The software design of the scenario generation portions of BSC

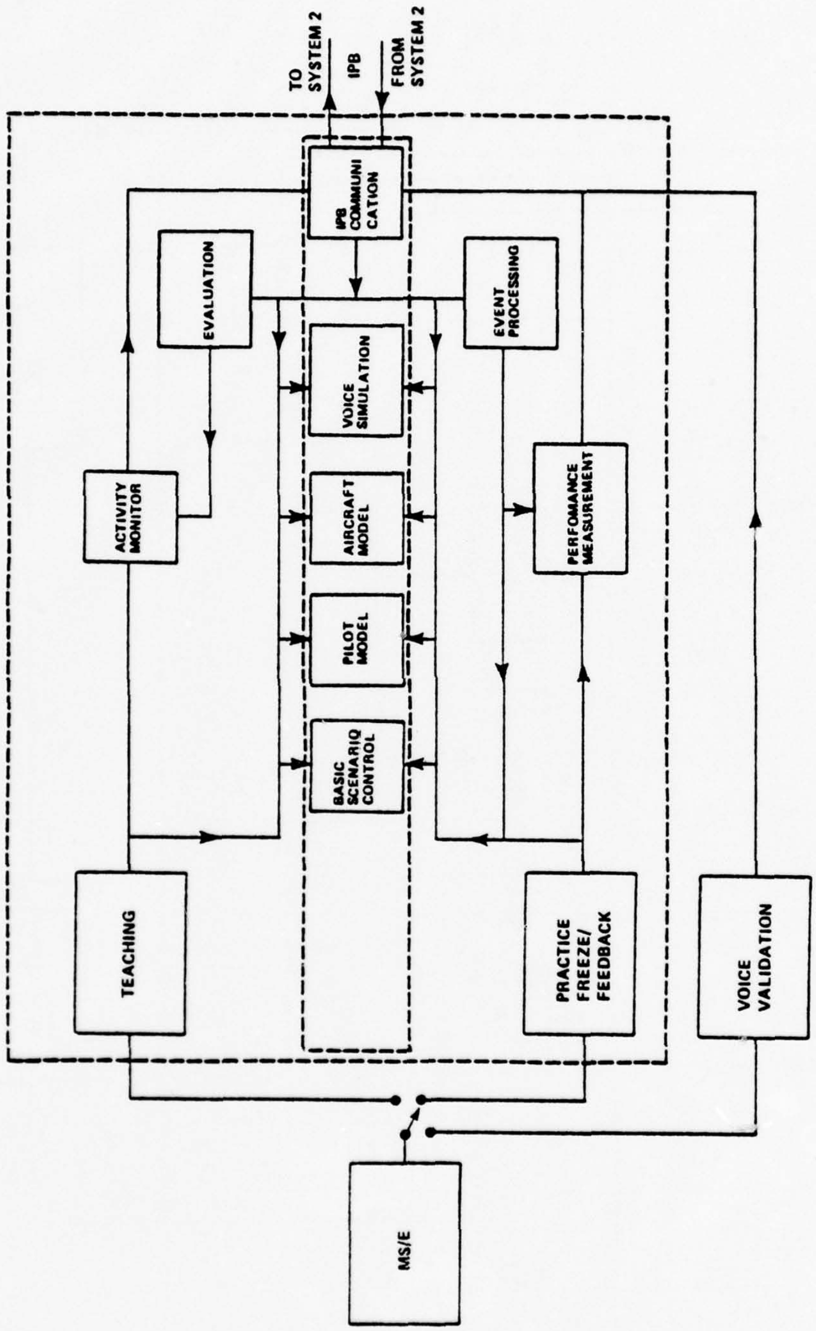


Figure 6a. System Software Structure (System 1)

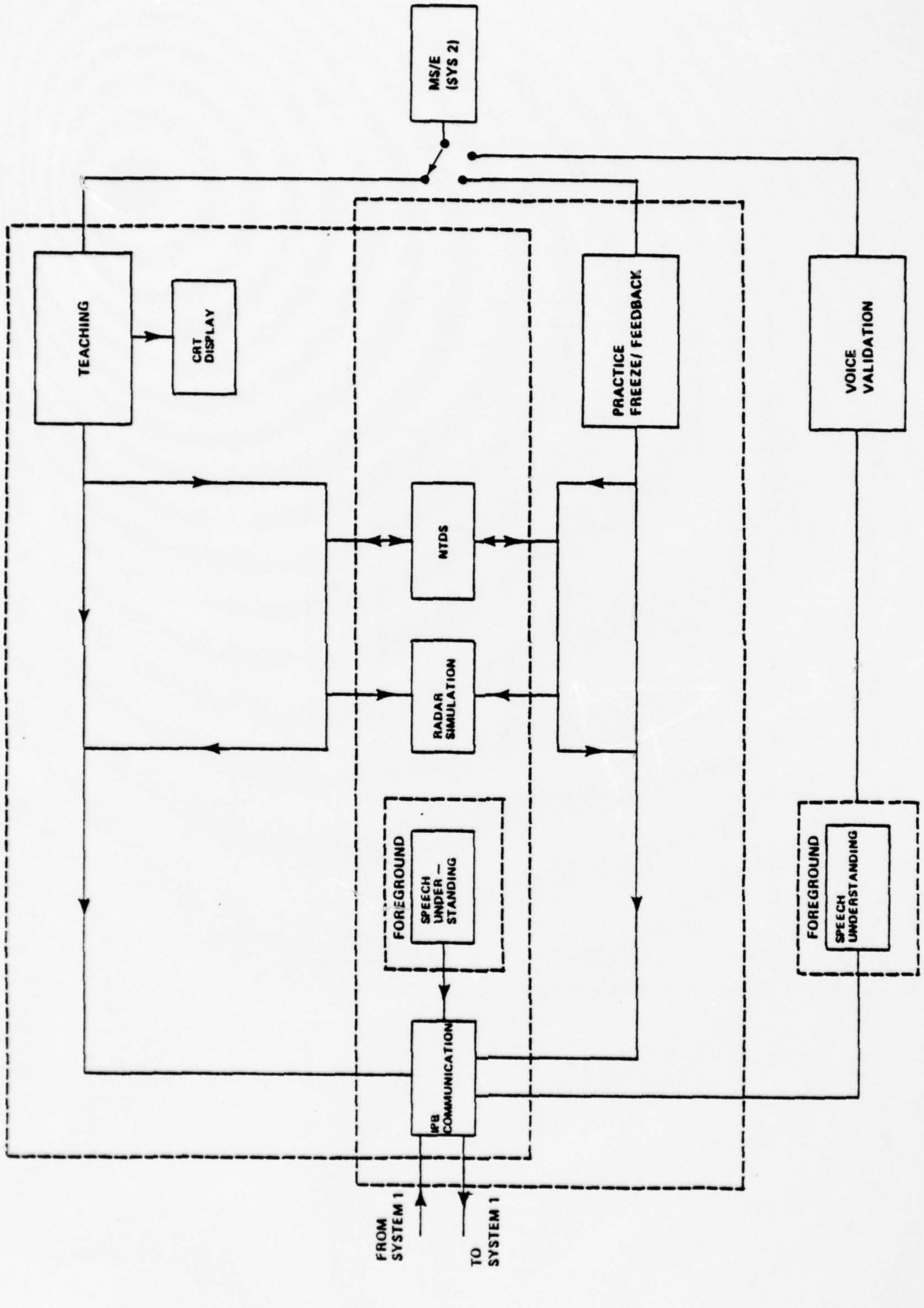


Figure 6b. System Software Structure (System 2)

TABLE 1. SCENARIO DEFINITION FILE

Scenario ID		
cc	1-80	Descriptive text
Default Conditions		
cc	1-3	Standard turn rate (degrees/sec)
cc	11-13	Hard turn rate
cc	21-23	Slow turn rate
Create Track		
cc	1	1
cc	6-7	track number 1 = ownship 2 = CAP — convention 3 = bogey 4 = stranger (if any)
cc	11-13	time (sec) from start of exercise, or — if negative — event number
cc	21	track type: 0 = unused track; only in track-data file) 1 = ownship 2 = CAP 3 = bogey 4 = stranger 5 = friendly 6 = other
cc	26-27	radius (miles) — initial position with respect to
cc	31-33	bearing — center of screen
cc	36-39	speed (miles/hr)
cc	41-43	heading
cc	46	motion model 1 = simple 2 = turning 3 = orbit 4 = stationary
cc	51-53	directed heading (if turning)
cc	56-58	turn rate (deg/sec; if turning)
cc	61-65	IFF code (4 or 5 digits; 0 = if not friendly)
cc	71-72	altitude (thousands of feet)
Drop Track		
cc	1	2
cc	2-13	same as above
Modify Dynamics		
cc	1	3
cc	2-13	same as above
cc	21	new motion model
cc	26-28	turn rate (if new motion is turning or orbit)
cc	31-33	directed heading (if turning)

TABLE 2. AVAILABLE EVENTS TO TRIGGER SCENARIO ACTIONS

Event	Description
1	The radio check was given
2	The vector for bogey was given
3	The bogey's bearing and range were given
4	The bogey's track and groundspeed were given
5	The stranger's bearing and range were given
6	The stranger's track and groundspeed were given
7	A stranger opening report was given
8	A bogey jinking left report was given
9	A bogey jinking right report was given
10	A negative contact report was given
11	The pilot's contact report was confirmed
12	After a stranger was reported, 4 sweeps elapsed
13	After a stranger was reported, 5 sweeps elapsed
14	After the pilot had a visual, 40 seconds elapsed
15	After the vector for bogey was given, 5 seconds elapsed
16	45 seconds elapsed
17	1 minute elapsed
18	After the CAP was located, 30 seconds elapsed
19	After the CAP was located, 45 seconds elapsed
20	100 seconds elapsed
21	2 minutes elapsed
22	After the bogey was detected, 20 seconds elapsed
23	After the bogey was detected, 3 sweeps elapsed
24	After the vector for bogey was given, 15 seconds elapsed
25	After the vector for bogey was given, 20 seconds elapsed
26	One sweep elapsed
27	After the bogey jinked, 20 seconds elapsed
28	After the bogey jinked, 30 seconds elapsed
29	After the bogey jinked, 30 seconds elapsed
30	After the bogey jinked, 40 seconds elapsed
31	The pilot gave a lost contact report
32	The exercise started
33	The bogey was detected
34	The bogey jinked left
35	The bogey jinked right
36	The pilot gave a correct contact call
37	The pilot gave an incorrect contact call
38	The cap was located
39	The cap symbol was built
40	The tracks were engaged
41	The pilot gave a judy call
44	After the vector for bogey was given, 4 sweeps elapsed
45	After the vector for bogey was given, 5 sweeps elapsed
46	5 sweeps elapsed
50	A stranger closed within 8 miles of the cap
51	A stranger closed within 7 miles of the cap
52	The pilot had a visual on the stranger
53	The stranger was opening
54	The stranger went outside 10 miles of the cap
56	After the pilot gaver a contact call, 18 seconds elapsed
57	After the pilot gave a contact call, 24 seconds elapsed
58	After the pilot gave a lost contact report, 15 seconds elapsed
59	After the pilot gave a lost contact report, 15 seconds elapsed
60	5 sweeps elapsed
62	The pilot gave a tally-ho
63	The stranger closed within 10 miles of the cap

include the following routines (the names of the routines appear in capital letters):

a. AIRINIT reads in all SDF.YX cards which represent event-initiated actions into a buffer, and their corresponding events into array TRGEVT.

b. BSCEVENT upon the occurrence of an event does a binary seach in TRGEVT for that event. If it is found, its SDF "card" is pulled out of the buffer and executed.

c. BSCPER checks the present time (ICLOCK) every second to see if it is equal to the time-intiated actions in the SDF.YX file. If it is, that "card" is executed and the next "card" is read in.

d. BSCACT executes the SDF cards. It determines which action to take (create a track, drop a track or modify dynamics) and calls the appropriate subroutines.

e. CTLTRAC creates a new track in the Track Data File (TDF).

f. CTLTRAC creates a new track from TDF.

Inter-processor Communications. Communication between the two computers is accomplished with binary writes across the Inter-processor Bus (IPB). Each system has a listening task whose only job is to receive messages sent to its system. Any routine can write information should it need to communicate with the other system.

a. IPBLIST is always listening for messages directed to System 1. When a message is received, it is loaded in a common area and IPBPROC is awakened to begin processing it.

b. MSGWAIT waits for messages forwarded from IPBLIST. It determines whether the source was NTDS or SUS, forwards the NTDS messages to the evaluation routines, or determines the confidence of the Speech Understanding Subsystem (SUS) phrase and sends it on to IPBPROC.

c. IPBPROC pieces together phrases from SUS to form a full message.

(1) CHECKMSG verifies that a SUS message is of high confidence, properly recognized by SUS, and is the type of message expected.

(2) SENDMSG first checks to see if the SUS message is in the active scenario and if so, notifies the pilot model to take the appropriate action.

d. IPBLISTN is a task which listens for messages directed to System 2. When a message is received, it is loaded in a common area and the resident MAIN task is notified for processing.

User Interface. BSC is also responsible for processing console (CRT-1) commands from the AIC-LAB user to start, freeze, proceed or abort the scenario exercise. CRTLIST is always listening for inputs from CRT-1. When an input is received, it is validated and, if correct, passes the request on to the resident MAIN task for processing.

PILOT MODEL. The pilot model simulates pilot actions in reference to observing other aircraft and responding to commands issued by the AIC. Three routines are involved:

a. PLTPER simulates the pilot's ability to observe aircraft on his radar and within his field of vision. It checks distances between the CAP and the bogey or strangers, if any. If the distance is small enough, various verbal calls are made depending on the distance.

b. PLTMSG determines if a SUS message is suitable for the present state of the pilot. Example: After a "radio check" pilot would be in state one and "Vector for bogey" would be suitable, but not the reverse. A "say again" is generated if required.

c. PLTACT responds verbally to a SUS message, if it is warranted, as well as contacting AIRCHG with new headings to alter the aircraft's flight if a command is issued to do so.

The voice simulation is accomplished through a predefined collection of phrase elements (see Table 3) stored on the disk (FRAZ.VO) and the following routines. Note that complete phrases are assembled by concatenation of these phrase elements.

a. VSCON (ASSEMBLER) places the phrase numbers which the calling routine specifies (via formal input arguments) in a queue.

b. VSOUT processes the queued arguments by multi-buffering from FRAZ.VO to the Votrax. To accomplish this, VSOUT uses RDFRAZ and WRFRAZ.

c. RDFRAZ (ASSEMBLER) reads the appropriate phonemes of the requested phrases number from FRAZ.VO.

d. WRFRAZ (ASSEMBLER) writes the phonemes to the Votrax.

AIRCRAFT MODEL. The AIC-LAB utilizes a simple aircraft model. Up to ten aircraft can be controlled, and their dynamics are maintained in a core and disk resident file called the Track Data File (TDF). (See Table 4.) Two routines maintain this file:

a. AIRPER updates once a second the X-Y coordinates of each track depending on its last position, speed direction, and type of motion (turn, simple, orbit, stationary). AIRPER also writes a new copy to disk for use by CPU-2's radar simulation.

TABLE 3. AIC LAB PHRASES ELEMENTS FOR VOICE SYNTHESIS

Say Again
Roger
Roger, Out
Roger, Stranger Opening
Roger, Rendezvous Point Sierra
Snake
Snake, Roger
Snake, Roger Looking
Snake, Has a Visual on the Stranger
Snake is in a
Orbit, Angels Twenty Ready for Control, Over
This is Snake, Point Whiskey, Twenty
Orbit, Over
Viper
Viper, Roger
Port
Port Hard
Anchor Port
Detach Port
Starboard
Starboard Hard
AnchorStarboard
Detach Starboard
Contact
Lost Contact
East Turn
Tighten Turn
Fox - One
Fox - Two
Breakaway
Continue
Judy
Out
Tally-Ho
Vector
Numbers 0 - 999,999

TABLE 4. TRACK DATA FILE

Word	Description
1	track type
	0 track not in use
	1 ownship
	2 CAP
	3 Bogey
	4 Stranger
	5 Friendly
	6 Other
2	Motion model
	1 Simple
	2 Turn
	3 Orbit
	4 Stationary
3	Speed (knots)
4	Turn rate (degrees/second)
5	Directed heading (degrees)
6	Heading
7	Current X position (miles) - Cartesian coordinates
8	Current Y Position (miles) - Cartesian coordinates
9	Speed in X direction (knots)
10	Speed in Y direction (knots)
11	Altitude (thousands of feet)
12	IFF number (if friendly, 0 otherwise)

b. AIRCHG modifies the dynamics of a particular track (turn, rate of turn, new heading, orbit, etc.).

RADAR SIMULATION. Radar simulation moves a sweep line across the radar circle whose diameter represents 64 miles. The sweep runs at 12 seconds per 360° cycle. As it reaches the locale of a particular aircraft, it brightens the sweep and video intensities, and as it moves away, the intensities are slowly lowered to those original states.

a. SWPINIT computes the points of all 400 radar sweep lines and stores them in arrays SWPX and SWPY.

b. CYCLIC draws sweep lines from ownship to successive sweep end points every 30 milliseconds to simulate a smooth, 12-second radar sweep.

c. GETDATA computes new angles between all videos and ownship every 12 seconds using function BLMANG. It also reads the updates TDF from disk for use in radar videos.

d. USEDATA transfers the new angles to active arrays for use by BLOOM.

e. BLOOM increases the intensity of the sweep and brightly displays the video in its new position when the sweep reaches the angles generated by GETDATA.

f. FADE is called once a second to dim videos gradually.

NTDS SIMULATION. The NTDS functions which were simulated in the AIC-LAB are shown in Table 5. The symbology is generated via a hardware character generator built into the Megatek display system. The firmware in the PROM upon which this generator operates was developed especially for the laboratory model. A typical display is shown in Figure 7.

a. BUTTONS accepts keyboard function codes or series of codes and simulates the appropriate NTDS actions on the Megatek console. PM&E and Teaching are notified of the actions for evaluation purposes. PER4 updates NTDS vehicle symbol coordinates every four seconds and also simulates the action of an NTDS tracker.

b. MOVSYM moves the NTDS symbols and their "speed leaders." Bogey bearing and range are displayed during engagements.

c. MOVHOOK moves the hook symbol if it exists.

d. NRBAL returns the track number of the track nearest the ball tab.

e. TURNOFF periodically turns off special Megatek pictures, such as the Illegal Action alert.

TABLE 5. NTDS FUNCTIONS

ENABLE BALL TAB:	Enables ball tab (B/T) at last used position
BALL TAB CENTER:	Places ball tab on ownship
HOOK:	Hooks closest track within 3 miles of B/T
SEQ:	Places tracks on the sequence list under close control
IFF:	Display mode 2 codes and altitude of aircraft close to B/T
GEOM:	Displays intercept geometry from hooked CAP to B/T
ORDERSEND:	Engages hooked CAP to B/T bogey
POSIT DATA:	Displays bearing and range from hook to ball tab
HDG:	Displays heading of hooked track
SPD:	Displays speed of hooked track
HDG— LFT:	Adjust hooked symbol heading -5°
HDG RT:	Adjust hooked symbol heading +5°
SPD- UP:	Adjusts hooked symbol speed up 0.1 mach
SPD— DN	Adjusts hooked symbol speed down 0.1 mach
POS COR:	Moves hooked symbol to B/T location
CLEAR:	Clears NED windows
SIF:	Selected Identification Feature
FUNCTION CODE:	Enters the following special functions from NED windows
11:	Cancels engagements
12:	Changes PIPIRO position to that of B/T
363:	Places hooked track on sequence list
1156:	Enters the data link status

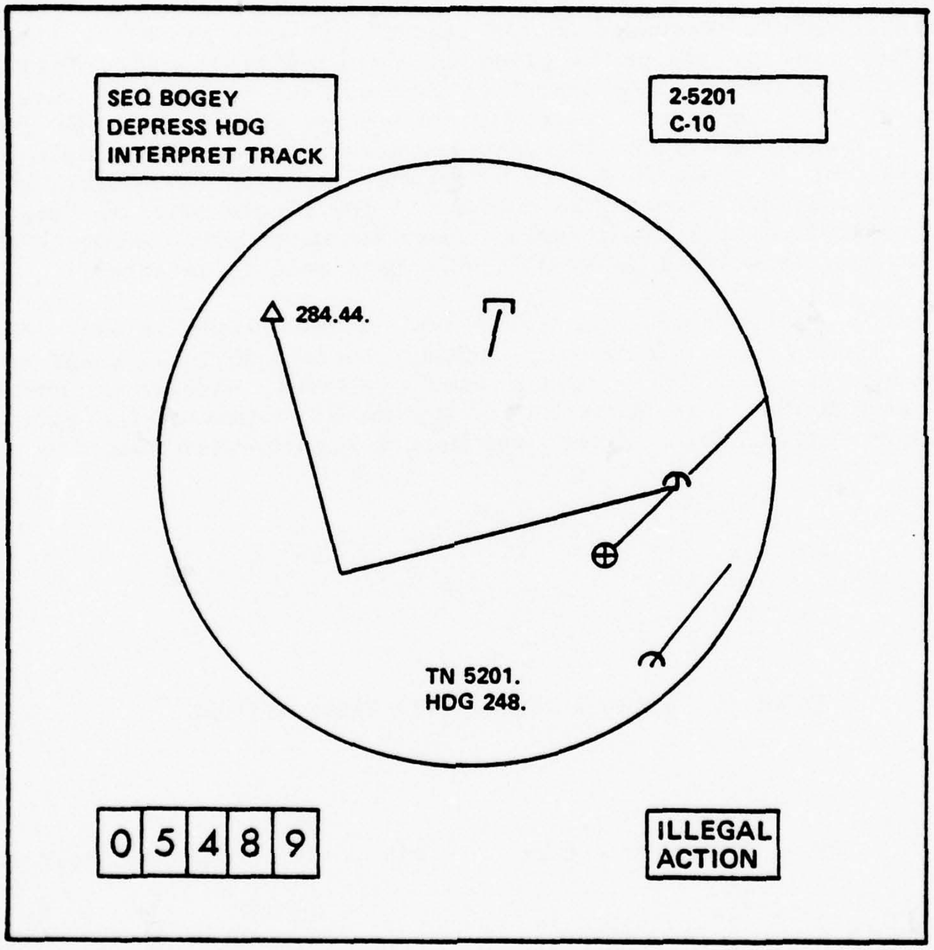


Figure 7. Typical Simulated NTDS Display

f. VFBCAL calculates intercept geometry (vector for bogey).

g. GEOM displays the intercept geometry and command heading.

TEACHING

The Teaching program is intended to investigate and demonstrate the feasibility and validity of automatically presenting step-by-step instructions to the AIC-LAB user. The program includes instructions for each of the learning objectives of Scenario 1 and Scenario 2.

Instructions are presented to the user ("trainee") on CRT-2. In addition, a brief clue or prompt is given on the display itself. The system will only continue through the exercises when correct actions are performed. In the event of an incorrect response, the system will return the user to the point of the error and the instructions are repeated. An example of the CRT presentations is shown in Figure 8 for the Scenario 1 objective, reporting bogey bearing and range. (The numbers in the figure refer to "pages" on the various CRT screens.) Teaching is operational in both Systems 1 and 2. The main program is swapped in by MS/E when this mode is selected.

The entire system relies on driver tables, one unique to each learning objective. These tables define step numbers, correct actions, steps to proceed to depending on validity of the user's actions, whether to check for accuracy, and whether some special activity should accompany the particular steps. These tables, then, direct the entire step-by-step function. (See Table 6.)

TABLE 6. STEP-BY-STEP DRIVER TABLE OPTIONS

SCENDF3
CRTOBJ3

EVENT	STEP	ACTION #	GOOD	BAD	SPEC ACTS	ACCURACY CK
1	1	10	2	1	92	0
2	2	10	3	2	0	0
3	3	3	4	5	1	3
4	4	45	0	1	2	0
5	5	45	0	1	2	0

1 *****BOGEY BEARING & RANGE*****

AFTER THE CAP HAS BEEN VECTORED TO THE BOGEY, THE BOGEY'S BEARING AND RANGE FROM THE CAP MUST BE REPORTED TO THE PILOT. IN ORDER TO PROVIDE ACCURATE REPORTS, YOU ARE RESPONSIBLE FOR ENSURING THAT THE SYMBOLS ARE UP TO DATE WITH THE RADAR VIDEO (REMEMBER WHERE THE "REAL" AIRCRAFT ARE!). THE SYMBOL ONLY REPRESENTS THE COMPUTERS ASSUMED POSITION. THE VIDEO CAN'T BE SEEN BY THE COMPUTER, SO YOU MUST TELL THE COMPUTER WHERE THE TRACKS ARE BY KEEPING THE SYMBOL ON TOP OF THE RADAR VIDEO.

WHEN YOU BEGIN THIS EXERCISE:

> THE CAP SYMBOL HAS BEEN BUILT
> THE CAP & BOGEY ARE ENGAGED
> VECTOR FOR BOGEY HAS ALREADY BEEN TRANSMITTED
> BOTH SNAKE & BOGEY ARE ON THE SEQUENCE LIST

DEPRESS NEW LINE TO CONTINUE.

2
RECALL THAT A SYMBOL IS UPDATED BY:

* PLACING THE TRACK IN CLOSE CONTROL VIA THE SEQ BUTTON OR BALL TAB/HOOK PROCEDURE

* MOVING THE BALL TAB TO THE CENTER OF THE FRONT LEADING EDGE OF THE VIDEO

* DEPRESSING POS COR (POSITION CORRECTION)

REMEMBER THAT ACCURACY IS MAXIMIZED BY PERFORMING THIS SEQUENCE JUST AS THE RADAR PASSES THE TARGET.

DEPRESS NEW LINE TO CONTINUE.

3
REPORT THE BOGEY'S BEARING AND RANGE BY:

> UPDATING THE CAP'S POSITION, IF NEEDED.

> UPDATING THE BOGEY'S POSITION, IF NEEDED.

> SEQUENCING TO THE CAP.

> INTERPRETING BOGEY'S BEARING(XXX) AND RANGE (YY) FROM THE PPIRO.

> TRANSMITTING THIS INFORMATION: "BOGEY XXX,YYP".

4
THAT IS CORRECT!
THIS PROCEDURE SHOULD BE PRACTICED UNTIL IT BECOMES ALMOST MECHANICAL.

DO YOU DESIRE A REPEAT?........STRIKE YES OR NO.

5
YOUR REPORT WAS NOT AS ACCURATE AS IT COULD BE.
DOUBLE CHECK TO MAKE SURE THAT THE SYMBOLS AND VIDEOS COINCIDE. THE ACCURACY OF YOUR REPORTS ARE CHECKED AGAINST THE "REAL" AIRCRAFT POSITIONS (RADAR VIDEO); NOT THE NTDS SYMBOL POSITIONS.

WE RECOMMEND THAT YOU TRY THIS PROCEDURE OVER.

DO YOU DESIRE A REPEAT?........STRIKE YES OR NO.

6

Figure 8. Teaching Presentation for Bogey Bearing and Range

The tables are created by an offline support program. The principal teaching routines are described below.

a. MAIN, which consists of the main programs for CPU-1 and CPU-2, opens files, creates tasks, and calls initialization routines.

b. TEACH uses the instructions from the driver table to determine which step to proceed to depending on the validity of the student's actions.

c. NEXT retrieves the stop instructions stored in the driver tables, and stores it in a common area for System 1 routines to access.

d. EVALUATE checks the specific action performed by the AIC with the anticipated correct action. It informs TEACH of its findings (good or bad). EVALUATE also directs special activities and accuracy checking when requested to do so.

e. CHEKIT handles accuracy checking for range, bearing, speed, and command heading. CHEKIT then informs TEACH of its findings.

f. SPECIAL is a "catch-all" subroutine to handle specific activities such as restarts, accepting any action until correct action occurs, etc.

g. RESTART redefines and reinitializes files in CPU-1 when the AIC requests a repeat of a teaching objective.

h. YANK displays text information on the CRT as a guide to the student's activities for each teaching step.

i. YANK1 displays on the Megatek console a brief version of the text displayed by YANK.

j. SETUP redefines and reinitializes Megatek picture and variables for restarts.

PERFORMANCE MEASUREMENT AND EVALUATION (PM&E)

In addition to the Teaching mode, the user may enter a Freeze and Feedback mode and a Practice mode. These modes of operation are performed by the PM&E programs, and support only Scenarios 1 and 2.

The Freeze and Feedback mode offers the student a practice environment in which he can request system monitoring of selected AIC learning objectives. If the system encounters a major error, it freezes and notifies the student of the error. At this point, the student can correct the problem and continue with the exercise. Note, however, that this mode gives no feedback except in the case of an error and only if the error occurs in one of the selected training areas. The Practice mode presents the student with an opportunity to operate on a given scenario without interruption. His actions are monitored and graded with respect to procedural correctness, accuracy, and timing as defined by AIC standards of operation, but there are no interruptions in the event of an error. In both modes, the student is presented with an evaluation report (see Figure 9) at the end of the exercise. As shown, the report provides a historical assessment of the student's strengths and weaknesses in the various learning objectives, and also a detailed explanation of errors made in the just-completed exercise. These error messages are identical to those given during run-time if the Freeze and Feedback options are selected.

This Performance Measurement algorithm may be characterized by the following attributes. Time restrictions among events can be enforced. Sequences of events can occur cyclicly. Constraints about the order of events can change dynamically. Any number of external actions san be taken when an event occurs. Complicated event-order constraints can be enforced. For example, if events A and B are to precede event C, the chain pointers for both A and B should include another "internal" event D, whose count-field is initially two. When both A and B have occurred, D's count will have been decremented to zero, causing D to occur. Thus, the relation "D must precede C" will be equivalent to "both A and B must precede C". In general, the relations "X must precede Y" and "X cannot occur after Y" may exist for any X and Y defined as actual external events, or internally in terms of other events.

Because the PM&E algorithms implemented in the AIC laboratory model may be of general interest, the following paragraphs describe it in greater detail.

THEORETICAL DISCUSSION. In the following discussion, capital letters (A, B, ...) designate numbers representing events. External events are those given to PM&E by the event preprocessing module. Internal events are created within PM&E itself in response to the occurrence of other events. Events were presented in Table 2.

PM&E can enforce two relations between events:

$A < B$; that is, event A must precede event B, and

$A \neg\!> B$; that is, event A cannot occur after event B;

where A and B can be internal or external.

For example,

"the fighter was located" < "the radio check was given";

"contact confirmed" ¬> "pilot gave an incorrect contact call."

An internal event A can be defined to have occurred if m out of n events B_1, B_2,..., B_n have or have not occurred. The notation for this is:

$$A \equiv (m\colon [\neg]\ B_1,\ [\neg]\ B_2,\ ..,\ [\neg]\ B_n).$$

PERFORMANCE REPORT FOR HOWELL

SUMMARY OF RUNS

DATE	DURATION	SCENARIO	CHECK-IN	V 4 B	BOGEY BRG/RNG	BOGEY TRK/GND	STRANGERS	BOGEY JINKS	CONTACTS
9/22/78	3: 3	1	WEAK	WEAK	WEAK	STRONG			
9/22/78	2:56	1	STRONG	WEAK	WEAK	MARGINAL			
9/22/78	2:51	1	STRONG	MARGINAL	WEAK	STRONG			
9/22/78	2:49	1	STRONG	STRONG	WEAK	STRONG			
9/22/78	3:14	1	STRONG	MARGINAL	WEAK	STRONG			
9/28/78	3: 0	1	STRONG	WEAK	WEAK	STRONG			
10/ 3/78	3:42	1	STRONG	WEAK	WEAK	WEAK			
10/12/78	2:55	1	STRONG	WEAK	WEAK	STRONG			
10/13/78	2:59	1	STRONG	WEAK	WEAK	WEAK			
11/ 7/78	0:59	1	WEAK	WEAK	STRONG	STRONG			
11/ 7/78	0:58	1	STRONG	WEAK	STRONG	STRONG			
11/ 7/78	2:34	1	WEAK	WEAK	WEAK	WEAK			
11/ 7/78	3:36	1	WEAK	WEAK	WEAK	WEAK			
11/ 9/78	2:48	1	STRONG	STRONG	WEAK	WEAK			
11/ 9/78	5:47	2	STRONG	WEAK	WEAK	WEAK	WEAK	STRONG	WEAK
11/ 9/78	4:41	2	STRONG	WEAK	WEAK	WEAK	WEAK	WEAK	WEAK
11/ 9/78	2:53	1	STRONG	MARGINAL	WEAK	WEAK			
12/ 5/78	4: 3	1	WEAK	WEAK	WEAK	STRONG			
12/ 5/78	3:41	1	STRONG	WEAK	WEAK	MARGINAL			
12/ 5/78	2:50	1	STRONG	STRONG	WEAK	STRONG			
12/ 5/78	2:52	1	STRONG	MARGINAL	WEAK	STRONG			
12/ 5/78	3: 0	1	WEAK	WEAK	STRONG	STRONG			
12/ 5/78	4: 3	1	WEAK	STRONG	WEAK	STRONG			
12/ 5/78	4:15	1	WEAK	WEAK	WEAK	STRONG			
12/ 5/78	2:53	1	WEAK	WEAK	WEAK	STRONG			
12/ 5/78	3: 0	1	STRONG	WEAK	WEAK	STRONG			
12/ 5/78	2:51	1	STRONG	WEAK	WEAK	STRONG			
12/ 5/78	2:55	1	WEAK	WEAK	WEAK	STRONG			
12/ 5/78	2:53	1	STRONG	WEAK	WEAK	STRONG			
12/ 6/78	2:43	1	WEAK	WEAK	STRONG	STRONG			
12/ 6/78	2:55	1	STRONG	STRONG	WEAK	STRONG			
12/ 6/78	5: 3	2	STRONG	WEAK	WEAK	WEAK	WEAK	WEAK	STRONG
12/ 6/78	2:48	1	WEAK	WEAK	WEAK	STRONG			
12/15/78	2:52	1	WEAK	WEAK	WEAK	WEAK			
12/18/78	2:50	1	WEAK	WEAK	WEAK	WEAK			
12/18/78	2:54	1	STRONG	STRONG	WEAK	STRONG			

ERRORS MADE IN MOST RECENT RUN

TIME	SEVERITY	ERROR
1: 6	MINOR	THE VECTOR FOR BOGEY WAS GIVEN, BUT THE COMMAND HEADING WAS 3-7 DEGREES OFF
1:16	MINOR	THE BOGEY'S BEARING AND RANGE WERE GIVEN, BUT THE RANGE WAS 2-3 MILES OFF
1:36	MINOR	THE BOGEY'S TRACK AND GROUNDSPEED WERE GIVEN, BUT THE SPEED WAS .1-.2 MACH OFF
1:43	MINOR	THE BOGEY'S BEARING AND RANGE WERE GIVEN, BUT THE RANGE WAS 2-3 MILES OFF
1:49	MINOR	THE BOGEY'S BEARING AND RANGE WERE GIVEN, BUT THE RANGE WAS 2-3 MILES OFF
2: 9	MAJOR	THE BOGEY'S BEARING AND RANGE WERE GIVEN, BUT THE RANGE WAS OVER 3 MILES OFF
2:22	MAJOR	THE BOGEY'S BEARING AND RANGE WERE GIVEN, BUT THE RANGE WAS OVER 3 MILES OFF

Figure 9. Student Evaluation Report

Some specific cases are:

$A \equiv (3{:}B_1,\ B_2,\ B_3)$, A has occurred when B_1, B_2, and B_3 have occurred.

$A \equiv (1{:}B_1,\ B_2)$, A occurs when B_1 or B_2 occurs.

$A \equiv (4{:}B)$, A occurs when B has occurred 4 times.

$A \equiv (2{:}B_1,\ B_2,\ -\ B_3)$, A occurs when B_1 and B_2 have occurred, and B_3 has not occurred.

In the definition, $A \equiv (m{:}B_1,\ B_2, \ldots)$, where m is called the count, which is used as follows: when an event B_i occurs which is in the definition of A, m is set to infinity if B_i was preceded by a "$\neg$" in A's definition; otherwise m is decremented by one. A occurs when m becomes zero. Note that m should be initially set to the number of events that must occur, as shown in the previous examples.

A list of actions ("special-actions") can be taken when an event occurs. Typical examples are:

a. Create or change $<$ and $\neg>$ relations

b. Start/stop/reset outside clocks

c. Set/reset "occurred" status of events

d. Change the count-fields (m) of events

e. Change special-action list for an event

f. Change definition of an internal event

g. Perform accuracy-checking on numbers

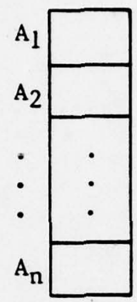
h. End the run

Proper choice of special actions will allow sequences of events to occur cyclicly, time constraints to be enforced, relations among events to change dynamically, and so on.

The data structure and algorithm which support the PM&E are described in the following paragraphs.

<u>Data Structure:</u>

There is an array of information records about each event A_i in the following format:



record —

OCC	CNT	BE	NAE	CP	SAP

— for event A_i;

OCC — occurred status for this event

CNT — present count m for this event

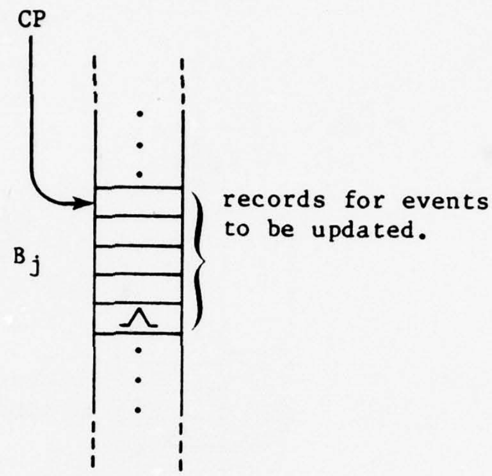
BE — event that must precede this one (can be null)

NAE — event this cannot occur after (can be null)

CP — pointer to list of internal events whose definitions involve A_i (can be null)

SAP — pointer to list of special-actions to be taken when A_i occurs (can be null)

The CP field points to a list of internal events to be updated, in the following format:



(array CHN)

Note: ⋀ Indicates End of File.

record

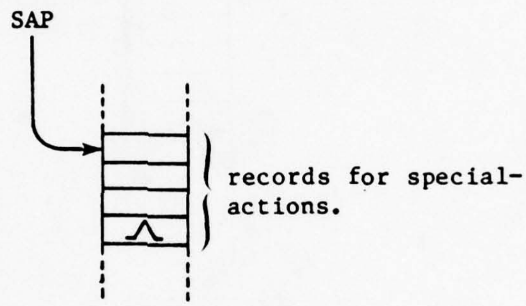
[¬]	EVT

;

[¬] — was B_j preceded by a "¬" in the definition of A_i? If so, it was not to have occurred.

EVT — event number for internal event B_j.

The SAP field points to a list of special-actions to be taken, in the following format:



(array DECKS)

record	OP	<parameters>	;

OP — operation-code for action to be taken (opcode).

<parameters> — counts, event-numbers, etc., associated with the special-action.

There is also a stack of records of events which are queued for occurrence. Each record is in the same format as those in array CHN.

Algorithm:

The PM&E algorithm can be defined in the folowing ALGOL-like language.

```
stack is initially empty;
when an event occurs
begin
     push event onto stack;
     if its CP field is not null then
     begin
          push its list of events in chain onto the stack;
          do the same for each new entry on the stack;
     end;
     repeat
          pop record for event Ai off the stack;
          if [ ¬ ] field is true then
               Aj's CNT field :=∞
          else
               Ai's CNT field : = * - 1;
          if Ai's CNT = 0 then {event Ai is ready to occur}
          begin
               if Ai's BE not null then {check event preceding Ai}
                    if event BE has not occurred then
                         signal error;
               if Ai's NAE not null then {event Ai can't occur after}
                    if event NAE has occurred then
                         signal error;
               if Ai's SAP not null then
                    do special-actions;
               Ai's OCC :=true; {event Ai has just occurred}
          end;
     until stack is empty;
end.
```

IMPLEMENTATION. PM&E uses a number of files for initializing arrays, recording run-performance, etc. See Figure 10. The principal PM&E files are:

a. PMTXT.0X: Test describing each event, plus some special texts

b. PMEVNT.0X: Read into EVINF array. Contains for each event:

(1) Special action pointer (may be null)

(2) Bit for unconditional special action

(3) Event that must have occurred before this one ("before-error"); may be null

(4) Bit indicating that the "before-error" is minor or major

(5) Event this one cannot occur after ("after-error"); may be null

(6) "After-error" is minor/major bit

(7) Present count field

(8) Chain pointer

c. PMEVT2.0X: Read into EVINF2. Learning-objective number associated with each event

d. PMDECK.0X: Read into DECKS. Contains lists of actions to be executed upon each event, if any

e. PMCLK.0X: Read into CLKINF. Contains initial values of clocks, and the events they cause to occur

f. PMCHN.0X: Read into CHN. Contains list of events to update upon an event, if any

(X = scenario id: 1 or 2)

The PM&E files are created by off-line programs; their content is shown (for Scenario 2) in Tables 7 through 12.

Routine PMSPER decrements the counts of all clocks with non-zero counts once every second. When a clock's count reaches zero, its associated event occurs via a call to EVENT. Subroutine EVENT translates an event of the form (source, message) into a single event number. This is given as a parameter to subroutine PMSEVNT, the front-end of the PM&E module. PMSEVNT checks the viability of an event. The event which just occurred is first pushed onto a stack, defined as array STK. If its chain-painter is not null, the events in CHN starting at the pointer's indicated position are also pushed. Then, for each event on the stack, that event's count-field is

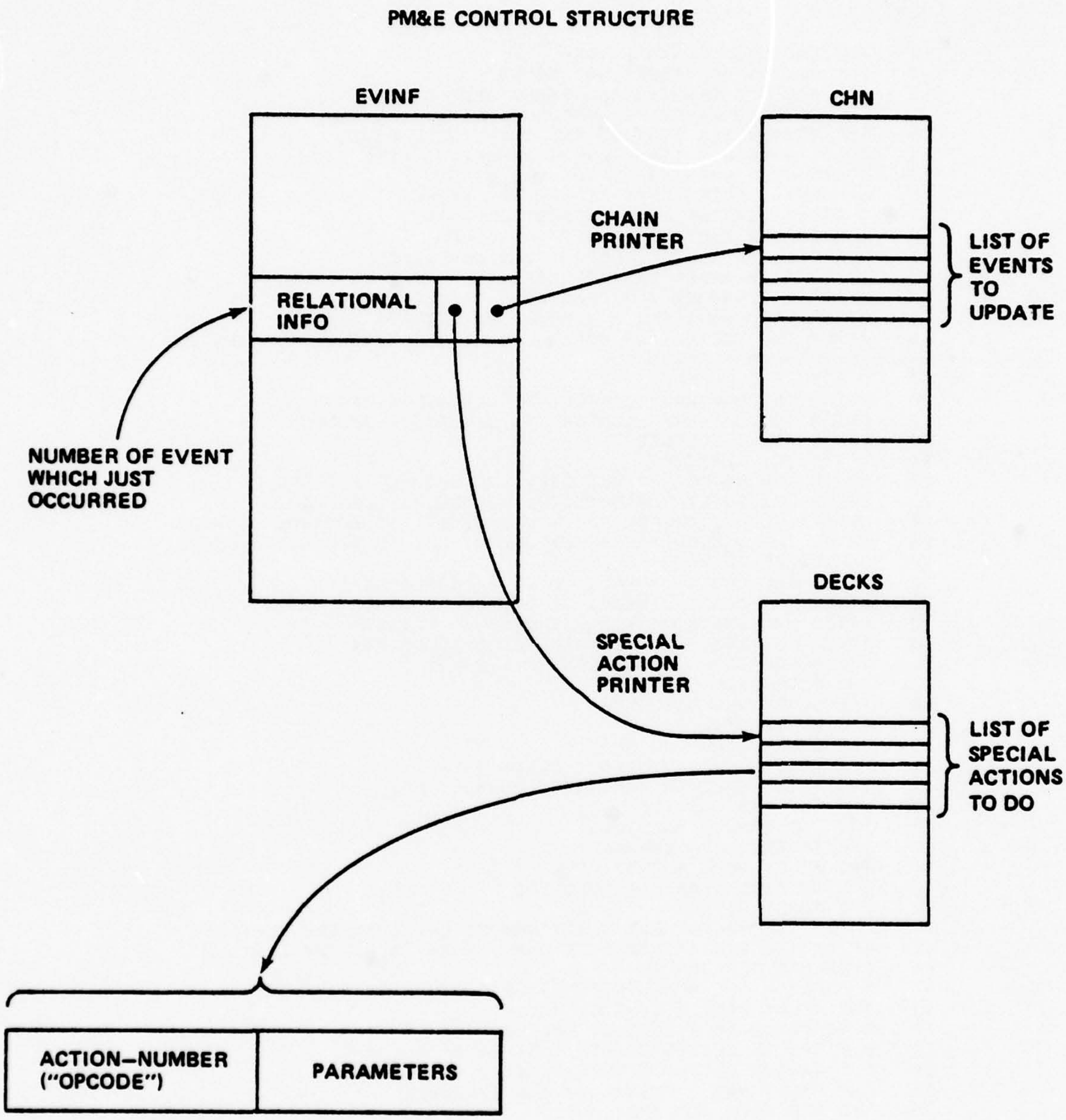


Figure 10. PM&E File Organization

TABLE 7. PMTXT FILE, SCENARIO 2

PMTXT SCENARIO ID = 2

EVENT	TEXT
1	THE RADIO CHECK WAS GIVEN
2	THE VECTOR FOR BOGEY WAS GIVEN
3	THE BOGEY'S BEARING AND RANGE WERE GIVEN
4	THE BOGEY'S TRACK AND GROUNDSPEED WERE GIVEN
5	THE STRANGER'S BEARING AND RANGE WERE GIVEN
6	THE STRANGER'S TRACK AND GROUNDSPEED WERE GIVEN
7	A STRANGER OPENING REPORT WAS GIVEN
8	A BOGEY JINKING LEFT REPORT WAS GIVEN
9	A BOGEY JINKING RIGHT REPORT WAS GIVEN
10	A NEGATIVE CONTACT REPORT WAS GIVEN
11	THE PILOT'S CONTACT REPORT WAS CONFIRMED
12	AFTER A STRANGER WAS REPORTED, 4 SWEEPS ELAPSED
13	AFTER A STRANGER WAS REPORTED, 5 SWEEPS ELAPSED
14	AFTER THE PILOT HAD A VISUAL, 40 SECONDS ELAPSED
15	AFTER THE VECTOR FOR BOGEY WAS GIVEN, 5 SECONDS ELAPSED
16	45 SECONDS ELAPSED
17	1 MINUTE ELAPSED
18	AFTER THE CAP WAS LOCATED, 30 SECONDS ELAPSED
19	AFTER THE CAP WAS LOCATED, 45 SECONDS ELAPSED
20	100 SECONDS ELAPSED
21	2 MINUTES ELAPSED
22	AFTER THE BOGEY WAS DETECTED, 20 SECONDS ELAPSED
23	AFTER THE BOGEY WAS DETECTED, 3 SWEEPS ELAPSED
24	AFTER THE VECTOR FOR BOGEY WAS GIVEN, 15 SECONDS ELAPSED
25	AFTER THE VECTOR FOR BOGEY WAS GIVEN, 20 SECONDS ELAPSED
26	ONE SWEEP ELAPSED
27	AFTER THE BOGEY JINKED, 20 SECONDS ELAPSED
28	AFTER THE BOGEY JINKED, 30 SECONDS ELAPSED
29	AFTER THE BOGEY JINKED, 30 SECONDS ELAPSED
30	AFTER THE BOGEY JINKED, 40 SECONDS ELAPSED
31	THE PILOT GAVE A LOST CONTACT REPORT
32	THE EXCERCIZE STARTED
33	THE BOGEY WAS DETECTED
34	THE BOGEY JINKED LEFT
35	THE BOGEY JINKED RIGHT
36	THE PILOT GAVE A CORRECT CONTACT CALL
37	THE PILOT GAVE AN INCORRECT CONTACT CALL
38	THE CAP WAS LOCATED
39	THE CAP SYMBOL WAS BUILT
40	THE TRACKS WERE ENGAGED
41	THE PILOT GAVE A JUDY CALL
42	A JINK DIRECTION WAS REPORTED
43	THE BOGEY JINKED
44	AFTER THE VECTOR FOR BOGEY WAS GIVEN, 4 SWEEPS ELAPSED
45	AFTER THE VECTOR FOR BOGEY WAS GIVEN, 5 SWEEPS ELAPSED
46	5 SWEEPS ELAPSED
47	4 BEARING AND RANGE REPORTS WERE GIVEN ON THE BOGEY
48	THE PILOT GAVE A CONTACT CALL
49	A RESPONSE TO A CONTACT CALL WAS GIVEN
50	A STRANGER CLOSED WITHIN 8 MILES OF THE CAP
51	A STRANGER CLOSED WITHIN 7 MILES OF THE CAP
52	THE PILOT HAD A VISUAL ON THE STRANGER
53	THE STRANGER WAS OPENING
54	THE STRANGER WENT OUTSIDE 10 MILES OF THE CAP
55	A STRANGER REPORT WAS GIVEN
56	AFTER THE PILOT GAVE A CONTACT CALL, 18 SECONDS ELAPSED
57	AFTER THE PILOT GAVE A CONTACT CALL, 24 SECONDS ELAPSED
58	AFTER THE PILOT GAVE A LOST CONTACT REPORT, 10 SECONDS ELAPSED
59	AFTER THE PILOT GAVE A LOST CONTACT REPORT, 15 SECONDS ELAPSED
60	5 SWEEPS ELAPSED
61	4 BEARING AND RANGE REPORTS WERE GIVEN ON THE STRANGER
62	THE PILOT GAVE A TALLY-HO
63	THE STRANGER CLOSED WITHIN 10 MILES OF THE CAP

TABLE 8. SPECIAL TEXTS FOR SCENARIO 2

PMTXT: SPECIAL TEXT PORTION

TEXT #	TEXT
0	THE BEARING WAS OVER 7 DEGREES OFF
1	THE RANGE WAS OVER 3 MILES OFF
2	THE SPEED WAS OVER .2 MACH OFF
3	THE COMMAND HEADING WAS OVER 7 DEGREES OFF
4	THE HEADING WAS OVER 7 DEGREES OFF
5	THE GEOGRAPHIC DIRECTION WAS OVER 40 DEGREES OFF
6	THE BEARING WAS 3-7 DEGREES OFF
7	THE RANGE WAS 2-3 MILES OFF
8	THE SPEED WAS .1-.2 MACH OFF
9	THE COMMAND HEADING WAS 3-7 DEGREES OFF
10	THE HEADING WAS 3-7 DEGREES OFF
11	THE GEOGRAPHIC DIRECTION WAS 30-40 DEGREES OFF

TABLE 9. PMEVT2 AND PMEVNT FILES FOR SCENARIO 2

PMEVT2 AND PMEVNT

EVENT	LO	ACTPTR	ALWAYS	MAGBEF	MAGNAFT	BEF	NAFT	CNT	CHAIN
1	1	11	0	0	0	37	1	0	2
2	2	19	0	0	0	1	0	0	2
3	3	55	0	0	0	33	41	0	7
4	4	30	0	0	0	33	41	0	2
5	5	87	0	0	0	0	0	0	15
6	5	89	0	0	0	0	0	0	11
7	5	80	0	0	0	53	0	0	2
8	6	47	0	0	0	0	35	0	1
9	6	47	0	0	0	0	34	0	1
10	7	94	0	0	0	48	36	0	18
11	7	91	0	0	0	48	37	0	18
12	5	0	0	1	0	6	0	0	2
13	5	0	0	0	0	6	0	0	2
14	5	0	0	0	0	0	0	0	0
15	2	0	0	0	1	40	0	0	2
16	1	0	0	1	1	38	0	0	2
17	1	0	0	0	1	38	0	0	2
18	1	0	0	1	1	39	0	0	2
19	1	0	0	0	0	37	0	0	2
20	1	0	0	1	1	1	0	0	2
21	1	0	0	0	0	1	0	0	2
22	2	0	0	1	1	2	0	0	2
23	2	0	0	0	0	2	0	0	2
24	3	0	0	1	1	3	0	0	2
25	3	0	0	0	0	3	0	0	2
26	3	26	1	1	1	0	0	0	3
27	6	0	0	1	1	42	0	0	2
28	6	53	1	0	0	42	0	0	2
29	6	0	0	1	1	4	0	0	2
30	6	0	0	0	0	4	0	0	2
31	7	73	1	0	0	0	0	0	2
32	1	1	1	0	0	0	0	0	2
33	2	14	1	0	0	0	0	0	2
34	6	0	0	0	0	0	0	0	9
35	6	0	0	0	0	0	0	0	9
36	7	0	0	0	0	0	0	0	13
37	7	0	0	0	0	0	0	0	13
38	1	7	0	0	0	0	38	0	2
39	1	0	0	0	0	38	39	0	2
40	1	0	0	0	0	1	0	0	2
41	7	69	1	0	0	0	0	0	2
42	6	0	0	0	0	43	0	1	2
43	6	33	1	1	1	0	0	1	2
44	4	0	0	1	0	4	0	4	2
45	4	0	0	0	0	4	0	5	2
46	3	43	1	0	0	47	0	5	2
47	3	0	0	1	1	0	0	4	2
48	7	60	1	0	0	0	0	1	2
49	7	0	0	0	0	43	0	1	2
50	5	0	0	1	0	55	0	0	2
51	5	0	0	0	0	55	0	0	2
52	5	101	1	0	0	0	0	0	2
53	5	0	0	0	0	0	0	0	2
54	5	0	0	0	0	7	0	0	2
55	5	0	0	0	0	63	52	1	2
56	7	0	0	1	0	49	0	0	2
57	7	0	0	0	0	49	0	0	2
58	7	0	0	1	0	3	0	0	2
59	7	0	0	0	0	3	0	0	2
60	5	84	1	1	0	61	0	0	2
61	5	0	0	0	0	0	0	4	2
62	7	71	1	0	0	0	0	0	2
63	5	0	0	0	0	0	0	0	2

TABLE 10. PMDECK FOR SCENARIO 2

PMDECK

ENTRY	OPCODE	FORMAT			
1	1	3	CLKNUM = 1	CLKVAL = 45	
2	1	3	CLKNUM = 2	CLKVAL = 60	
3	1	3	CLKNUM = 5	CLKVAL = 100	
4	1	3	CLKNUM = 6	CLKVAL = 120	
5	0	2	APTR = 0	EVNT2 = 0	
6	0	2	APTR = 0	EVNT2 = 0	
7	1	3	CLKNUM = 3	CLKVAL = 30	
8	1	3	CLKNUM = 4	CLKVAL = 45	
9	0	2	APTR = 0	EVNT2 = 0	
10	0	2	APTR = 0	EVNT2 = 0	
11	4	1	CHBIT = 0	EVNT1 = 33	EVNT2 = 2
12	0	2	APTR = 0	EVNT2 = 0	
13	0	2	APTR = 0	EVNT2 = 0	
14	4	1	CHBIT = 0	EVNT1 = 2	EVNT2 = 3
15	4	1	CHBIT = 0	EVNT1 = 2	EVNT2 = 4
16	1	3	CLKNUM = 7	CLKVAL = 20	
17	1	3	CLKNUM = 8	CLKVAL = 36	
18	0	2	APTR = 0	EVNT2 = 0	
19	6	2	APTR = 2	EVNT2 = 0	
20	1	3	CLKNUM = 0	CLKVAL = 5	
21	1	3	CLKNUM = 9	CLKVAL = 15	
22	1	3	CLKNUM = 10	CLKVAL = 20	
23	1	3	CLKNUM = 11	CLKVAL = 12	
24	5	2	APTR = 64	EVNT2 = 2	
25	0	2	APTR = 0	EVNT2 = 0	
26	3	1	CHBIT = 1	EVNT1 = 26	EVNT2 = 0
27	1	3	CLKNUM = 11	CLKVAL = 12	
28	0	2	APTR = 0	EVNT2 = 0	
29	0	2	APTR = 0	EVNT2 = 0	
30	6	2	APTR = 4	EVNT2 = 0	
31	0	2	APTR = 0	EVNT2 = 0	
32	0	2	APTR = 0	EVNT2 = 0	
33	1	3	CLKNUM = 12	CLKVAL = 20	
34	1	3	CLKNUM = 13	CLKVAL = 30	
35	1	3	CLKNUM = 14	CLKVAL = 30	
36	1	3	CLKNUM = 15	CLKVAL = 40	
37	3	1	CHBIT = 1	EVNT1 = 4	EVNT2 = 0
38	3	1	CHBIT = 1	EVNT1 = 8	EVNT2 = 0
39	3	1	CHBIT = 1	EVNT1 = 9	EVNT2 = 0
40	3	1	CHBIT = 1	EVNT1 = 42	EVNT2 = 1
41	0	2	APTR = 0	EVNT2 = 0	
42	0	2	APTR = 0	EVNT2 = 0	
43	3	1	CHBIT = 1	EVNT1 = 47	EVNT2 = 4
44	3	1	CHBIT = 1	EVNT1 = 46	EVNT2 = 5
45	0	2	APTR = 0	EVNT2 = 0	
46	0	2	APTR = 0	EVNT2 = 0	
47	3	1	CHBIT = 1	EVNT1 = 43	EVNT2 = 1
48	3	1	CHBIT = 1	EVNT1 = 8	EVNT2 = 0
49	3	1	CHBIT = 1	EVNT1 = 9	EVNT2 = 0
50	3	1	CHBIT = 1	EVNT1 = 34	EVNT2 = 0
51	3	1	CHBIT = 1	EVNT1 = 35	EVNT2 = 0
52	0	2	APTR = 0	EVNT2 = 0	
53	3	1	CHBIT = 1	EVNT1 = 42	EVNT2 = 1
54	0	2	APTR = 0	EVNT2 = 0	
55	6	2	APTR = 3	EVNT2 = 0	
56	1	3	CLKNUM = 9	CLKVAL = 0	
57	3	1	CHBIT = 1	EVNT1 = 3	EVNT2 = 0
58	1	3	CLKNUM = 10	CLKVAL = 0	
59	0	2	APTR = 0	EVNT2 = 0	
60	1	3	CLKNUM = 16	CLKVAL = 18	
61	1	3	CLKNUM = 17	CLKVAL = 24	
62	3	1	CHBIT = 1	EVNT1 = 49	EVNT2 = 1

TABLE 10. PMDECK FOR SCENARIO 2 (CONT)

63	0	2	APTR = 0	EVNT2 = 0	
64	6	2	APTR = 2	EVNT2 = 0	
65	0	2	APTR = 0	EVNT2 = 0	
66	0	2	APTR = 0	EVNT2 = 0	
67	0	2	APTR = 0	EVNT2 = 0	
68	0	2	APTR = 0	EVNT2 = 0	
69	1	3	CLKNUM = 11	CLKVAL = 0	
70	0	2	APTR = 0	EVNT2 = 0	
71	2	2	APTR = 0	EVNT2 = 0	
72	0	2	APTR = 0	EVNT2 = 0	
73	3	1	CHBIT = 1	EVNT1 = 41	EVNT2 = 0
74	3	1	CHBIT = 1	EVNT1 = 46	EVNT2 = 5
75	3	1	CHBIT = 1	EVNT1 = 47	EVNT2 = 4
76	1	3	CLKNUM = 11	CLKVAL = 12	
77	1	3	CLKNUM = 18	CLKVAL = 0	
78	1	3	CLKNUM = 19	CLKVAL = 15	
79	0	2	APTR = 0	EVNT2 = 0	
80	0	2	APTR = 0	EVNT2 = 0	
81	0	2	APTR = 0	EVNT2 = 0	
82	0	2	APTR = 0	EVNT2 = 0	
83	0	2	APTR = 0	EVNT2 = 0	
84	1	3	CLKNUM = 23	CLKVAL = 60	
85	3	1	CHBIT = 1	EVNT1 = 61	EVNT2 = 4
86	0	2	APTR = 0	EVNT2 = 0	
87	6	2	APTR = 5	EVNT2 = 0	
88	0	2	APTR = 0	EVNT2 = 0	
89	6	2	APTR = 6	EVNT2 = 0	
90	0	2	APTR = 0	EVNT2 = 0	
91	6	2	APTR = 11	EVNT2 = 0	
92	0	2	APTR = 0	EVNT2 = 0	
93	0	2	APTR = 0	EVNT2 = 0	
94	6	2	APTR = 10	EVNT2 = 0	
95	3	1	CHBIT = 1	EVNT1 = 37	EVNT2 = 0
96	1	3	CLKNUM = 17	CLKVAL = 0	
97	3	1	CHBIT = 1	EVNT1 = 48	EVNT2 = 1
98	1	3	CLKNUM = 16	CLKVAL = 0	
99	3	1	CHBIT = 1	EVNT1 = 10	EVNT2 = 0
100	0	2	APTR = 0	EVNT2 = 0	
101	4	1	CHBIT = 0	EVNT1 = 0	EVNT2 = 54
102	1	3	CLKNUM = 21	CLKVAL = 0	
103	1	3	CLKNUM = 22	CLKVAL = 0	
104	1	3	CLKNUM = 23	CLKVAL = 0	
105	0	2	APTR = 0	EVNT2 = 0	
106	0	2	APTR = 0	EVNT2 = 0	
107	0	2	APTR = 0	EVNT2 = 0	
108	0	2	APTR = 0	EVNT2 = 0	
109	0	2	APTR = 0	EVNT2 = 0	
110	0	2	APTR = 0	EVNT2 = 0	
111	0	2	APTR = 0	EVNT2 = 0	
112	0	2	APTR = 0	EVNT2 = 0	
113	0	2	APTR = 0	EVNT2 = 0	
114	0	2	APTR = 0	EVNT2 = 0	
115	0	2	APTR = 0	EVNT2 = 0	
116	0	2	APTR = 0	EVNT2 = 0	
117	0	2	APTR = 0	EVNT2 = 0	
118	0	2	APTR = 0	EVNT2 = 0	
119	0	2	APTR = 0	EVNT2 = 0	
120	0	2	APTR = 0	EVNT2 = 0	
121	0	2	APTR = 0	EVNT2 = 0	
122	0	2	APTR = 0	EVNT2 = 0	
123	0	2	APTR = 0	EVNT2 = 0	
124	0	2	APTR = 0	EVNT2 = 0	
125	0	2	APTR = 0	EVNT2 = 0	
126	0	2	APTR = 0	EVNT2 = 0	

TABLE 11. PMCLK FILE FOR SCENARIO 2

PMCLK

CLOCK	VALUE	EVENT
0	0	15
1	0	16
2	0	17
3	0	18
4	0	19
5	0	20
6	0	21
7	0	22
8	0	23
9	0	24
10	0	25
11	0	26
12	0	27
13	0	28
14	0	29
15	0	30
16	0	56
17	0	57
18	0	58
19	0	59
20	0	14
21	0	12
22	0	13
23	0	60
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0
31	0	0

TABLE 12. PMCHN FILE FOR SCENARIO 2

PMCHN

ENTRY	EVENT	NOT-TYPE
0	0	0
1	42	0
2	0	0
3	44	0
4	45	0
5	46	0
6	0	0
7	47	0
8	0	0
9	43	0
10	0	0
11	55	0
12	0	0
13	48	0
14	0	0
15	55	0
16	61	0
17	0	0
18	49	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0

updated. If the countfield is now zero, the event is defined to have occurred, thereby checking for "before-error" and "after-error" conditions. SPCACT is called if the event's special action pointer is not null and no major errors occurred. If any errors occurred, minor or major, the error handler (ERRHANDL) is called.

SPCACT is given a special-action pointer to a location in DECKS containing the first of possibly several special actions to be executed. Each location contains an action-number (opcode) field and some parameter fields. The possible actions are:

a. Set clock N to value T

b. Enable/Disable the occurrence of an event

c. Change a relation: (A and B are event numbers)

   (1) A must occur before B

   (2) A cannot occur after B

d. New special-action pointer for Event A is P

e. Upon event A, before- or after-error is minor or major

f. Special-action is unconditional for event A

g. End the exercise normally (wakes up .MAIN)

h. Call KLUDGE for accuracy-checking

KLUDGE checks for accuracy of numbers recognized by SUS. They are command-headings, bearings and ranges, and headings and speeds. If a number is grossly inaccurate, it is a major error; if somewhat so, a minor error. The error-handler is called for both kinds of errors.

The error-handling routine, ERRHANDL, records the detected error in <Name> .EL, the student's error-log. If the error was major, and the freeze and feedback option which the event (causing the error) corresponds to is set, then an error-message is composed in the form: [the text for the event causing the error] [special texts] [and] [text for another event that was or was not to have occurred]. The system is then frozen and the error message is displayed on CRT-2. Otherwise, the run proceeds normally.

When a run has ended normally, the main program calls PMSREP to grade the student's performance for each of the learning objectives in the scenario. The grading rules are, for each learning objective:

a. any major error: weak,

b. >N minor errors: weak,

c. >=M and <=N minor errors: marginal, and

d. <M minor errors: strong.

where M and N are defined for each learning objective. The resulting summary is written to <Name> .PS, the student's performance summary log, and to CPU-1's console. If desired, both the summary and error logs are printed as a performance report by a call to WRITREP.

SECTION V

SYSTEM UTILIZATION

INTRODUCTION

The AIC laboratory model was exposed and used by three AIC instructors (one retired) and three subjects not previously familiar with operational AIC responsibilities. Unfortunately, technical difficulties prevented the complete integration of speech recognition capabilities into the remainder of the system in time to thoroughly evaluate and exercise all aspects of all scenarious for all users.[1] Nevertheless, considerable experience was gained with the system and much was learned even in these preliminary sessions. Logicon intends to continue using the model in the near future to investigate and refine the functional characteristics of AIC training systems.

The following subsections highlight comments and suggestions made relative to the features implemented in the laboratory model. In addition, they describe the lessons learned through the design, implementation, and test phases of the project.

SIMULATION

Radar and NTDS provided relatively high-risk or questionable areas to be addressed by the model. How effective would commercial systems be in simulating the radar/symbology presentations? How much effort would it be to emulate the required NTDS functions?

The high resolution, vector-stroke graphics techniques produce a very "clean" display. The radar videos used in the laboratory model were considered too crisp and clear; rather, they should look more like a "blob" of brightened phosphor. The orientation of the video should be perpendicular to the radar sweep. The video must be generated more realistically by the sweep. The entire scope requires more clutter (additional aircraft, weather, land mass, etc.) to be realistic. Although a clean, crisp display is adequate-in fact beneficial-in the early phases of training, instructors agree that the AIC must become used to working with the more realistic, cluttered, systems before moving into live air control. How realistic is still undefined.

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1 See NAVTRAEQUIPCEN 78-C-0044-1. Briefly, the major problems were achieving good accuracy on phrases ending in bearing or heading information, such as "bogey tracking 217," and developing the reference data for recognition of connected digits. Additional speech stylizations, namely pausing before the three-digit sequence and developing a dynamic programming recognition algorithm, were suggested as solutions to the first problem. Additional R&D will be required to ease the burden of creating the LCSR data base. Alternatively, other methods for performing LCSR should be considered.

The emulation of NTDS functions was relatively straightforward once they were defined. The problem was in specifying the button actions in sufficient detail to provide accurate simulation. For example, does "enable Ball Tab" cause the ball tab to appear at ownship, the center of the screen, or at its last location? Every seemingly insignificant detail must be defined in order for the emulation to retain face validity.

The utilization of the commercial graphics, keyboard, and joystick for NTDS promulgated much discussion concerning the NTDS console(s) to be used in the experimental prototype training system as well as in the ultimate operational AIC/ASAC trainer. Often contradictory comments made by the AIC instructors and others exposed to the system included:

a. Operational gear (UYA-4 and Operational NTDS programs) is an absolute requirement in the training environment.

b. Development of a look-alike, synthetic console would be adequate for early stages of training.

c. A synthetic console would be useful only if it could accept live radar and radios.

d. Emulating NTDS programs is not feasible because they are always changing.

e. New consoles are also being developed, and hence one must take a long and studied look at which console to emulate in developing a synthetic console.

f. A transfer of training could occur on a totally commercial training-equipment-based system.

Clearly, the question of operational versus simulation is a complex and hotly debated issue. No one seemed to doubt that the cost savings would be substantial if the simulated console and program were used. But training effectiveness and maintaining operational/simulation functional compatability are not so easily agreed upon. As will be suggested in the next section, this would appear to be a valid and fruitful research issue for the experimental prototype system.

TEACHING

A step-by-step instructional approach was viewed as effective. The following comments typify those made during utilization of the laboratory model.

a. The system must provide flexibility within the teaching mode. The student should be free to perform the utilitarian NTDS functions in addition to those requested by the step-by-step instructions.

b. Most errors made by the students are founded on his inability to accurately track the symbols on video. Early exercises need to concentrate on keeping symbols on the video.

c. The computer instructions need to emphasize the job more than the buttons. For example, the student should first learn that he must let the NTDS computer know which aircraft he intends to control; secondly, he should be taught that this is done by building a CAP symbol during the check-in procedure; third, he should be taught the step-by-step procedure to be followed in order to build a CAP symbol on <u>this</u> console with <u>this</u> program.

d. Highly synthetic, unrealistic scenarios can be effective teaching tools. For example, shipboard personnel often use the NTDS programs (with symbols only) for proficiency training.

e. The transitions from element to element in the teaching programs must be accomplished smoothly and quickly.

f. One of our major concerns centers around motivating the system users. Little will be accomplished if the presentations cannot hold the student's interest or create the desire to acquire more knowledge. It appears that the majority of personnel receiving AIC training is gradually shifting to "short term" individuals, both in terms of time spent in the Navy as well as time left before discharge. This adds an additional burden and should be strongly considered when planning all phases of the experimental prototype.

A problem encountered throughout the laboratory model effort was confusion about the goals of the program. This was especially evident when discussing the Teaching mode. The model's Teaching programs were not specifically designed to teach a "student" to use the model. Step-by-step instructions are just one element of an automated training system. The fact that we did not (and probably could not) actually fully train anyone with the model is not a disparaging commentary. The purpose was to investigate and demonstrate how a complex skill task might be addressed in an automated training system.

PERFORMANCE MEASUREMENT AND EVALUATION

The Freeze and Feedback mode represented a demonstration and investigation or an errorless learning strategy in which the user is not allowed to proceed if he makes a major error. A complete evaluation of this and the Practice mode was not possible because of the problem encountered with the speech recognition. Nevertheless, the following observations were made:

a. Error-reports should include more detail. For example, they should describe performed button sequences versus correct sequences, or the probable cause of inaccurate advisories (tracking, etc.).

b. Run-time feedback might include judicious use of voice generation.

c. Standards must be adjusted to meet the expected skills of the student. For example, an accuracy of ±5° may be fine as an end-of-course standard, but is it probably too tight in the beginning.

The whole issue of standards and their measurement provided considerable learning opportunities. The performance measurement system needed to support AIC training is very much unlike that of other controller tasks previously addressed, e.g., GCA. AIC performance must be measured not only in terms of accuracy and timeliness, but also in procedure. The resulting software is more akin to a procedures monitor than has been previously required.

The laboratory system also hinted that the arbitrary accuracy standards (e.g., ±3°, ±2 miles) may, in fact, be highly unrealistic. This is an area rich in research and development opportunities, since there have never been any studies on AIC performance using their operational console as there have been with pilots, for example. A definitive assessment of these issues will probably require data extraction and reduction using operational or (non-existant to-date) simulated NTDS consoles and programs. At this point, it is doubtful that anyone really knows how accurate even the best AIC has been.

Finally, it became clear that the standards must depend on the range between CAP and bogey. If the hostile aircraft is forty miles from the CAP, say, the bearing surely does not require the same accuracy as if they were ten miles apart. Whereas these observations may seem self-evident, in point of fact they were generated from observation and utilization of the AIC laboratory model.

SCENARIO 3

The teaching and performance measurement functions were not implemented for Scenario 3. The system simulation did support it. However, due to time constraints, we did not exercise this scenario. The results, conclusions and recommendations made in this report were consequently derived from and validated against the tactical job of the AIC in conducting CAP-to-bogey intercepts. But insofar as the performance measurement and evaluation features of the system were only implemented in Scenarios 1 and 2, there is minimal impact on the project's goals because Scenario 3 was not exercised.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

GENERAL REMARKS

The development and utilization of an AIC laboratory model was a worthwhile and fruitful effort. Much was learned about AIC instructional features, simulation requirements, performance measurement, and speech understanding. As a high-risk developmental research effort, the model, understandably, was not entirely free from its share of problems. The companion studies in speech recognition affected the utilization and full exploitation of the model adversely. Fortunately, however, the experiences with the speech understanding programs will save time and dollars later when the experimental prototype is being designed and developed. The AIC task is a complex one. In this study, we learned both what to do and what not to do. Taken in total context, we conclude that automated AIC training is both viable and effective.

CONTINUING RESEARCH INTEREST

This laboratory effort has had interesting spinoff benefits. In addition to supporting the front-end analysis of an automated prototype training system, it has suggested specific points of research interest during that prototype effort.

JOB VERSUS OPERATIONS. AIC training has traditionally concentrated on the mechanics of console functions needed to support the AIC's jobs. This approach places heavy emphasis on the specific console and operational NTDS program. As new consoles and programs are released to the fleet, expanded or increased training is required.

Because of the inevitability of changes in the console and program, however, other approaches should be studied. We suggest that the experimental prototype system investigate the effectiveness of a training program which emphasizes the job first, but integrates simulated console operations later. Such a system would not only teach the basic skills, but it would also teach the capability to transfer those skills to another piece of operational hardware. The student must understand that he is being taught to be flexible, to expect change and to fit each specific task or exercise into the overall job of the AIC.

SIMULATED CONSOLE. Beacuse of the interest and controversy surrounding use of a simulated (look-alike) NTDS console and emulated NTDS program, we suggest that the experimental prototype system address this issue as well.

RECOMMENDED TRAINING SYSTEM SPECIFICATIONS

The following subsections delineate the functional capabilities which we recommend for consideration in the development of an experimental prototype system. These recommendations are based upon studies conducted during this front-end analysis project.

TRAINING FUNCTIONS. The Experimental Prototype AIC Training System (AIC-PROTO) should train student controllers to prepare them for live air intercept control. The training system should teach the knowledge (jobs) and the necessary skills (controls) to conduct basic air intercepts, air combat maneuvers, special mission aircraft, setups, friendly/tanker join-ups, and other required tasks. Table 13 contains the learning objectives to be addressed.

Following an entry test to verify appropriate entry level, the trainee should be taught:

a. To extract information from an NTDS UYA-4-type device (e.g., bearing and range from the interceptor to the hostile aircraft target (bogey), bogey track and ground speed)

b. To use an IFF (UPA-59A)-type device, radio-telephone voice communications, one- and two-way data links

c. To calculate setups for aircrews in a training environment. This procedure allows the aircrews to train from a desired target aspect angle

d. To respond to real-world conditions including emergency situations, special mission aircraft, jamming, radar fades, land masses, splits, and formation flying

e. To follow the aircraft for safety of flight, to avoid other aircraft and to maintain the aircraft in a desired area

f. To provide vectors and heading recommendations for friendly/tanker join-ups, to vector to the bogey when it appears the interceptor is on the wrong target, and to establish a nearest collision

g. To coordinate with the Ship's Weapons Coordinator (SWC), Track Supervisor (TRK SUP), and the Learning Supervisor

A post-test should verify that the trainee can indeed perform the established learning objectives addressed by the AIC-PROTO.

TABLE 13. LEARNING OBJECTIVES TO BE ADDRESSED BY AIC-PROTO

Range and bearing from interceptor to target	The student will be required to ensure that the symbols are on video prior to using range and bearing information. Although the bogey will be tracked by other NTDS operators (trackers), the AIC may update the track. The Combat Air Patrol (CAP) will be command tracked by the NTDS; the AIC will be able to modify the heading, speed and altitude to conform to the actions of the CAP.
Target track and speed	The AIC will bring the bogey symbol into close control and interpret the bogey track and ground speed from the NTDS console's Data Read Out (DRO).
Jinking	The AIC will be able to detect a drastic change in track, speed or altitude by using the track history functions of NTDS. The direction will be easily detected, while both speed and altitude jinks will show up as ground speed jinks.
NTDS failure	The AIC will perform the above tasks without the use of the computer program. The AIC will continue to give needed information until the program is restored.
Update TAO/SWC	The Tactical Action Officer (TAO) will know the progress the CAP is making, an estimate as to probability of making the intercept and the results of the intercept. The AIC will coordinate this information through the SWC.
Splitting bogeys	The AIC will obtain the bogey's composition by interpreting the radar scope, from trackers and other means. At the moment any separation is detected it will be critical that the aircrews are notified so they can react.
Composition and formations	The interpreting of composition and formation will dictate the tactics the aircrew will employ. The AIC will be alert to provide this information and any change.
ACM	Air Combat Maneuvering (ACM) challenges the AIC to interpret what is happening in a dogfight. Timing, positioning tankers, splitouts, other aircraft joining the fight, and friendly cover are some of the areas AICs must learn to be effective during ACM. Communication must be realistically taught during multiplane engagements.
Missions for CAPs, other than intercepts and engagements	Weather reconnaissance flights, where the AIC gives range, bearing and area control information to the aircrew, relays weather reports and assists in emergencies. Barrier patrol and search-and-rescue are other examples of missions for purposes other than intercept and engagements.
Jamming and Interference	The AIC's job is the same during adverse conditions. The student will be taught to do what he can, however, to continue to give the best information available.
One- and two-way data link operations	The AIC must be able to initiate data link operations, send target and orders to the aircraft and interpret the track information sent back down.
The training environment	The aircraft requires setups of specific target aspect angles to allow training from desired positions. For disengagements, a recommended breakaway heading will be necessary.
Friendly tanker join-ups	A low-risk missed intercept for low fuel CAP will be taught by turning the tanker and allowing the CAP to join on him.

SYSTEM OPERATION CONCEPTS. The training sessions, taken as a whole, should provide for the application of behavioral technology to promote learning. Individualized instruction, carefully structured around levels of achievement, and a highly automated multiphased approach should lead the way to an effective training system.

AIC-PROTO should provide a training environment which places the responsibility for learning on the student. The system operation concept is shown in Figure 11. Although no system can force learning, AIC-PROTO should challenge the student to achieve obtainable short-range goals. These goals, or levels of achievement, should gradually introduce new learning objectives, progressing from easy to hard, simple to complex. Levels of achievement should put the emphasis on achievement and motivation.

AIC-PROTO should adapt to the individual needs of the trainee, teaching only what the trainee needs, as long as is necessary. The aircraft's speed, antenna rotation rate, the skill of the pilot/tracker, the amount of material, and the number of repetitions, etc., each should be adjustable to fit the particular needs of the trainee.

By maximizing the level of automation, the system should minimize requirements of the instructor during the teaching, grading and critiquing phases of training. AIC-PROTO should provide standards, objective grading on the learning objectives, and criteria for advancement.

AIC-PROTO might provide optional warmup drills, selectable from a menu of learning skills previously addressed. A multiphased approach could then introduce new learning objectives:

a. Teaching and Validation mode: While voice data are collected and validated, new material could be introduced in a step-by-step fashion, with AIC-PROTO demonstrating the correct method of performance and giving the trainee a clear picture of his tasks. AIC-PROTO could then allow the trainee to correctly perform the new task while the system monitors performance. This should ensure that the trainee learns the material correctly the first time. The trainee should be able to challenge the learning objective before going into the freeze and feedback mode.

b. Freeze and Feedback mode: AIC-PROTO could integrate the new material with the previously covered material, freezing on errors of the new material only. Feedback could be given and the trainee could correct the mistake.

c. Grading mode: AIC-PROTO could provide the trainee an opportunity to practice the material presented thus far, giving results and recommendations for more practice, remedial training or advancement.

d. Annotated Replay mode: AIC-PROTO could (optionally) replay previous practice runs (either in their entirety or only selective portions), critiquing in detail the student's performance.

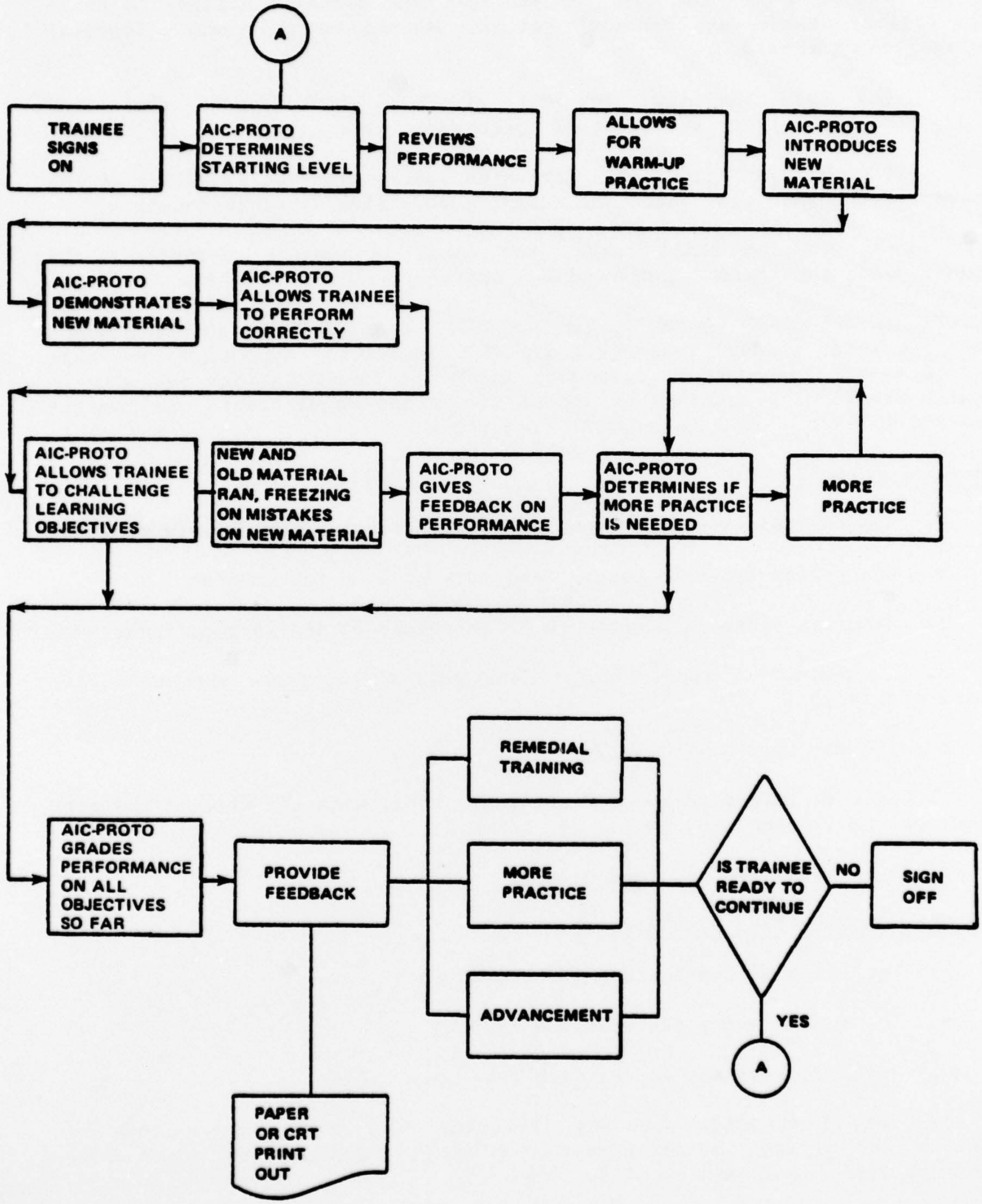

Figure 11. Prototype System Operation Concept

e. Remedial Training mode: Based upon the system's ability to diagnose trainee weaknesses, remedial training should be provided. Remedial training categories are:

(1) Knowledge tasks, for which AIC-PROTO should restate the procedures, time windows, or statement of appropriate rules.

(2) Simple skill tasks, for which the system should go back to the freeze and feedback mode where the learning objective was introduced.

(3) Complex skill tasks, for which it should re-instruct the student using a different instructional approach.

OPERATIONAL SHIPBOARD EQUIPMENT SIMULATIONS. The AIC-PROTO should provide realistic radar (video) presentations; NTDS functions, symbology, and data read outs; IFF information; data link and other communications methods. A careful preliminary analysis of system simulation requirements has identified the following minimum necessary functions.

Radar Simulation.

a. A sweep rate variable from one to five revolutions per minute (RPM)

b. Controlled fades to ensure dead reckoning by the student

c. Aircraft video size variable to represent an SPS 48-type radar

d. A maximum of twenty-four videos with a selectable size of small, medium and large

e. IFF associated with select videos

f. Gate to determine the IFF challenge area, with the size of the gate selectable on the training device

g. Jamming, noise and land masses

NTDS Console Functions Simulation.

a. The quick action buttons for the AC mode

b. The number entry controls and display

c. Required displays in the data read outs (DROs)

d. The fixed action buttons including drop track, enter mode and radar, radar select, enter offset, intensity controls and range scale, selection from 16, 32 and 64 miles

e. The track ball and controls for the ball tab

f. Radio channel and controls

g. Three intercommunications channels and controls

h. A plotting scope which rotates to compensate for magnetic variation

NTDS symbology simulation.

a. Ten friendly, four CAP, six hostile, four unknown air symbols to include speed leaders, assignment and engagement bars

b. Four friendly and four hostile surface symbols

c. Balltab, hook, TACAN station, ownship, geometry lines between symbols, a fly-to-point capability, and a command tracking function

d. The plan position indicator read out (PPIRO) which displays information on the scope of the track in close control. (For example, range and bearing information will appear by an engaged track.)

e. Twenty lines drawn to be fixed geographically or slaved to a symbol. Individual lines may be dropped without affecting the others.

IFF Simulation. A UPA-59A type IFF unit to include the following job tasks:

a. Assist in tracking friendly aircraft using IFF

b. Locate friendly aircraft using IFF

c. Identify one friendly aircraft from another using IFF

d. Determine height on friendly aircraft using IFF

e. Provide positive identification using IFF and asociated PPI presentations that include:

(1) Bracket pulse
(2) Identification pulse
(3) Emergency pulse
(4) Mode 4
(5) Gate pulse

The required switches, lights and alarms should also be functional.

AIRCRAFT, ENVIRONMENT, AND ASSOCIATED PERSONNEL SIMULATION. The prototype system should simulate the other factors, which taken together with the aforementioned shipboard systems, will provide the effective AIC simulation environment.

Aircraft Performance Simulation.

a. Turn rate: 1.5, 3, 4.5 and 6 degrees per second

b. Speed: 0.5 to 2.5 mach. Acceleration and deceleration to represent standard fighter performance.

c. Altitude: variable from 0 to 50,000 feet. Rate of climb and descent to represent standard fighter performance.

Environment Simulation. Wind should affect the aircraft tracks. Wind should be programmable from scenario control and manual input. Wind can range from 0 to 100 knots. Each 5000 feet of altitude can have a different wind.

CAP/Bogey Pilot Simulation. A pilot model should react to a given situation under three modes of operation: manual, controlled and responsive.

a. The manual mode should allow the aircraft to follow only the trainee's commands.

b. The controlled mode should respond to predefined scenarios.

c. The responsive mode should react to the trainee's information and recommendations. Feedback will be given from the weapon system which is representative of an F4-type system with a degrading factor to allow optimum use of the AIC. This mode will be extremely effective in preparing an AIC for live air control. Three degrees of efficiency should be selectable: weak, normal, and strong.

Tracker Simulation. A tracker model should react to the trainee's accuracy when calling range and bearing. The more accurate the trainee is, the better the tracking. If the trainee is weak in providing accurate range and bearing calls, the hostile symbols should not be tracked accurately.

Communications Simulation. The internal communications between the AIC, SWC and the TRK SUP should be simulated and reactive. When SWC will assign targets to the AIC by voice, the symbol alerts should reflect the actions. The AIC should be able to coordinate with the TRK SUP on tracking and radar performance problems. One channel should allow the Learning Supervisor to communicate with the trainee.

The external voice communication between the CAP and AIC should function through a radio control panel and footkey. Voice simulation during ACMs should be particularly realistic to provide effective training.

The data links, both one- and two-way, should simulate tactical situations. Voiceless data link hops should be available for training.

AUTOMATED SPEECH. The automated training system should monitor the controller's verbal behavior. The system should understand the standard AIC transmissions from the trainee and react appropriately. Moreover, since the system acts as the aircrew and other personnel, it should produce all transmissions from the aircrew, SWC and TRK SUP, as well as simulate the student in demonstrations and exercise replays.

The automated speech recognition system should allow the trainee to input verbal information into the training system. The AIC-PROTO should interpret the predefined vocabulary, react if needed and determine if the transmission was needed and met the required standards. Speech recognition would thus facilitate the automated instructional features.

The trainee issues two types of transmissions: orders and information. The CAP model should react to the situation or to the AIC's orders. In a tactical situation the CAP model should react to the AIC heading/speed information as advisory information. The training environment would require the CAP and bogey models to react to the AIC recommendations. Speech recognition should provide the basis for this simulation.

The primary use for automated speech generation should be to simulate the aircrew's voice. It is important to associate the video on the scope with the aircrew. If voice generation isused for too many things, it would be hard for the trainee to make the necessary correlation. One distinctive voice should simulate the aircrew, with another voice simulating the AIC during demonstrations and replays. Introductory presentations and any other uses (except the aircrew simulation) could use the AIC voice.

NAVTRAEQUIPCEN's research interests in the utilization of the automated speech technologies in training systems design will dictate other functional requirements of the system, such as data extraction and recognition accuracy evaluations.

INSTRUCTOR MODEL. A reasonable design goal for the experimental prototype system is a fully automated system that would relegate to the computer the exercise selection, performance measurement, and student critiquing functions normally performed by an AIC instructor. This objective translates into several systems-level functional requirements which are briefly outlined below.

The heart of an automated training system is the decision logic of the automated instructor. Algorithms within the model select what, when, and how the various learning objectives are presented to the trainee. The instructor model should present the material, measures performance, provides feedback, diagnoses problem areas, and recommends subsequent training modalities.

Present Training Material. The system should provide the functional capabilities to:

a. Teach underlying concepts and job tasks through textual, pictorial, and verbal presentations.

b. Demonstrate in show-and-tell fashion how these jobs are implemented with the consoles available to the AIC.

c. Interact with the trainee using computer-assisted instruction (CAI)-like functions to verify the student's understanding of his job. It should, however, avoid trick questions, deliberate misleads, or ambiguous propositions.

d. Provide remedial training to students with identified weaknesses in specific learning objectives.

Measure Trainee Performance. The system should provide a performance measurement capability which can detect errors of the following types:

a. Procedural errors: The AIC took some action or issued a command or advisory when he should not have done so.

b. Timeliness errors: The AIC failed to take an action or issue a command or advisory when he should have done so.

c. Frequency errors: The AIC failed to provide an advisory as often as he should have.

d. Accuracy errors: The information related in the command/advisory was not accurate relative to:

(1) True aircraft positions, and/or

(2) NTDS provided information.

The AIC training problem poses the challenge of developing a uniquely flexible performance measurement capability. Although many of the basic skills, such as reporting target track and speed, are relatively straightforward; other areas such as ACM and setups require more sophisticated schemes. Using setups in the training environment as an example, recall that the trainee controls the movement of both aircraft (the CAP and bogey). Using a grease pencil, the trainee calculates the desired target aspect angle and plots (on the scope face) the planning bearing and the fighter's and bogey's headings. After acquiring the desired separation, he turns the aircraft for the intercept. The algorithm should tolerate errors that could, in fact, jeopardize the entire run. The instructor model should be able to grade the student for any given situation, even if the situation is unsatisfactory; the trainee should be graded on the given situation.

Provide Feedback. The instructor model of the prototype system should provide feedback to both the training manager (instructor) and the trainee. In terms of instructor feedback, it should:

a. Provide various levels of information (under instructor control) on an individual trainee's performance. This feedback should include go/no-go decisions at the terminal objective level on the one hand, down to detailed quantitative information at the enabling objective level, on the other hand.

b. Enable the instructor to monitor or replay specific runs or exercises with annotated comments directed specifically to the instructor. An annotated hardcopy graphic representation of an air control exercise would be highly desirable. This capability would enable the instructor to confer with the student about specific problems or strengths at their leisure, thus adding considerably to the level of instructor automation and freedom, which is a primary design goal of the system.

c. Present an overview of the trainee's progress through a level of achievement and/or the entire course. Information on the amount of time (percentage and absolute) spent in remedial training would be of benefit to both the instructor and training system designer.

d. Provide information on a class of trainees. This information, together with the trainee specific data, would provide the instructor with an overview of the student's performance in relation to other students. Moreover, this type of information would support the evaluation of the automated training system itself.

e. Present the results of trainee evaluation. This information should include, as a minimum, an indication of areas of strengths and weaknesses of the trainee. Recommendations and rationale for advancement, additional practice, or remedial training should be provided.

f. Format all instructor feedback in a way that facilitates quick comprehension by the instructor. Maximum use should be made of graphic presentations such as curves and bar charts.

In terms of trainee feedback, the instructor model should:

a. Selectively freeze upon detection of errors, providing instructional feedback to the student concerning the error and recommended corrective action.

b. Reinforce correct behavior by providing positive feedback when a trainee has demonstrated the proper behavior.

c. Provide end-of-run, end-of-level, end-of-day, and end-of-course information at various (and selectable) levels of detail. Textual, graphic, and voice feedback methods should each be considered as appropriate.

d. Provide an annotated replay capability of the previously run exercise to facilitate automated trainee coaching.

Diagnose Trainee Strengths and Weaknesses. An important function of the automated training system is to properly infer (from data provided by the performance measurement function) the relative strengths and weaknesses of the trainee. In the prototype, "relative" should refer to:

a. The trainee's current performance relative to the absolute behavioral standards determined by an AIC training task analysis

b. The trainee's current performance relative to his current point in the training syllabus

c. The trainee's current performance relative to other students who have been trained (satisfactorily or not) by the prototype

Because it is an experimental prototype, the functional requirements imposed upon this aspect of the instructor model, i.e., diagnosis of strengths and weaknesses, should emphasize flexibility and ease of modification. A simple table-look-up scheme should be considered. For each (quantitative) performance measurement variable relating to the learning objectives, a range of values should be established (initially guessed at, but subsequently determined empirically). This range of values should categorize the trainee's performance as indicative of a behavioral strength, borderline, or a weakness. This construct would provide a functional basis for the experimentation with the training system to impact this aspect of the instructor model. The result of this performance evaluation, as with the performance measurement, should provide the material for the trainee and instructor feedbacks discussed earlier.

Direct the Training Syllabus. A final functional requirement imposed upon the instructor model should be to marshall the system's simulation, voice technologies, and instructional features and construct a syllabus which will enable the trainee to learn the required material at a challenging but achievable pace. More specifically, the system should:

a. Provide a pre-test to validate that prospective trainees meet the minimum entry-level qualifications.

b. Provide an ordered sequence of instructional material including typical scenarios and exercises which will form the basis for teaching the AIC tasks and skills.

c. Develop decision algorithms to determine when the trainee should advance through the syllabus, or indeed be directed to previously covered (remedial) exercises. These algorithms should be automated and adaptive, but the instructor should always be given the opportunity to override the decisions of the computer model.

d. Provide a post-test or final examination to validate that the trainee is prepared to control live aircraft and has met the standards for behavior defined for the system. Deficiencies on the part of the trainee should be noted with a cross-reference to specific tasks and skills and to that portion of the syllabus wherein the skill was taught.

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